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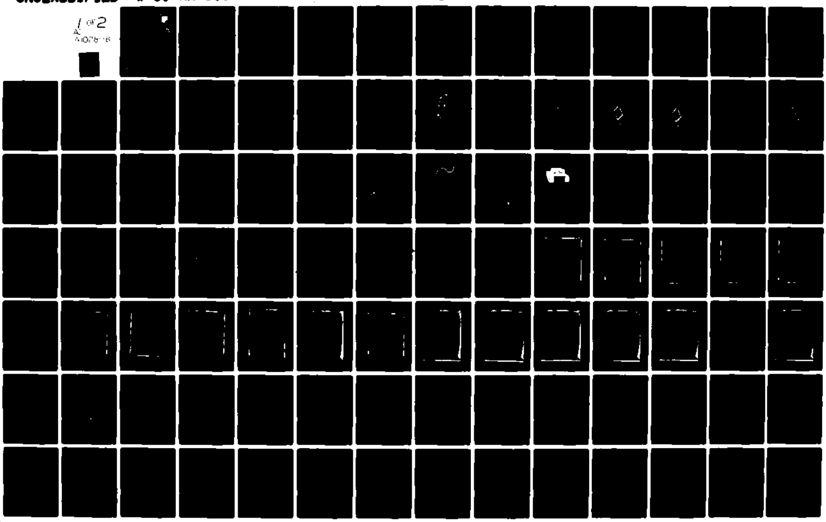

LEVEL II

RADC-TR-81-120
Final Technical Report
June 1981

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SCANNING CURSOR ADAPTABILITY

Synectics Corporation

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report details the research and findings related to the Scanning Cursor Adaptability Study. The data herein pertains to the review of automated cartographic and scanning cursor programs, digitizing device vendors, the analysis of interface requirements, and recommendations and conclusions. Appendices detailing interface specifications and technical references are also included.

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Table

1. TECHNICAL PROBLEM

Rome Air Development Center (RADC) is engaged in an extensive program to enhance automation in the cartographic field. This program is concerned with both hardware and software techniques and spans the area from initial input to final output. The Scanning Cursor Adaptability effort was undertaken to determine the adaptability of the scanning cursor to various commercially available opaque and backlighted digitizing devices. This research is designed to enhance the application of scanning cursor technology to the cartographic field.

2. GENERAL METHODOLOGY

Cartographic experimentation to date has resulted in four general findings. First, the manual digitizer (as it is presently available) is not fully applicable to the volume demands and the detailed requirements of cartographic data conversion. Relative to the raster approach, there has been continued but slow improvement. (Conversion quality is not adequate for general use and a total raster concept must still be considered as incomplete.) Third, the approach embodied in the digitizer-drum combination demonstrates considerable promise but exhibits definite disadvantages. Finally, the Scanning Cursor program evidences promise; therefore it is currently advantageous to extend that technology to other digitizing tables.

The methodology followed by Synectics Corporation incorporated the review of the overall cartographic program, current input procedures, and feature identification procedures; the analysis of the elements of the scanning cursor program to date and of all commercially available digitizers (both backlighted and opaque); and finally, a ranking of all candidate digitizing tables.

The reviews paid particular attention to the cartographic input process and to the constraints implied by manual digitizers. Also determined were the character of the feature identification processes, the nature of the input and edit procedures, and the data formats commonly utilized.

The analyses were completed with respect to Scanning Cursor hardware performance (including expected accuracy and repeatability), interface requirements for operation with a Gradicon digitizer, and software algorithms developed for generation with the Gradicon digitizer/HP21MX computer.

The analyses of all commercially available digitizers pertained to three basic requirements; the active digitizing area was to measure at least 40" by 60", the accuracy limits were ± .005", and the repeatability parameter measured ± .001".

The final stage of the study was the review of all of the data which had been gathered. All candidate digitizing tables that met the physical and electronic/electrical characteristics necessary for the Scanning Cursor operation were ranked. The criteria utilized for the ranking process pertained to four areas. First, the ease and practicality of hardware interfacing the Scanning Cursor to the tables chosen was evaluated. The relative costs of the required electronic interface between the table and subsequent data processing equipment it may be connected to comprised a second criterion. A third area of evaluation was the functional definition of required software modifications. The final, and perhaps most significant, criteria were expected performances relative to digitizing, error, and throughput rates.

3. TECHNICAL RESULTS

The analysis of commercially available digitizers yielded a list of prospective vendors which totalled 29. The staff realized that not all of these prospects manufactured their own table; however, it was anticipated that such nonmanufacturers might identify additional manufacturers. Out of the 29 companies researched, only seven were identified as actual manufacturers of tables. The remaining 22 companies were eliminated from consideration due to at least one of the reasons listed below.

a. They are a marketing company representing a table manufacturer.

b. The digitizer they market is not a table with a free cursor but rather a scanner or image projection digitizer.

c. They sell commercial digitizing systems that use one of the manufacturer's tables. (None of these companies claim to alter the original table.)

d. They are no longer in business, have been bought by another company, or have changed their name.

The seven companies which were determined actual manufacturers of tables were:

a. Altek Corporation;

b. Aristo Graphics Corporation;

c. [Data Automation] Interface Electronics, Inc.;

d. GTCO Corporation;

e. Summagraphics;

f. Talos Systems Inc; and

g. Wang.

Two of these vendors were eliminated from consideration. Data Automation underwent a reorganization which prevented them from supplying Synectics Corporation with the information necessary to include their table in the interface analysis. After the report was 75% complete Synectics received information from Interface Electronics, Inc. stating that they [Interface] were building and marketing the Data Automation table. However, the recent entry into this area resulted in uncertainty as to the options which will be available. The other vendor which was eliminated from consideration was Wang; their table could not satisfy the SOW requirements.

The ranking of the five remaining vendors was calculated on a "weighted value" basis. Two characteristics (resolution and accuracy) were not included in the calculation because they were specifically determined by SOW requirements. The four factors on which the ranking was based are listed below.

a. Weighted Table Price

b. Engineering Availability

c. Sample Rate Evaluation

d. Backlighting

Each factor could receive a maximum value of one (1).

The weighted table price was determined by dividing the lowest table cost ($11,447) by the respective manufacturers' table costs.

The engineering availability factor was weighted with the value of one (1) being assigned where engineering services were offered and a value of zero (0) being assigned where such services were not available.

The sample rate evaluation was accomplished by dividing the manufacturers' sample rates by the optimum rate of 110.

Finally, the backlighting factor was weighted in the same fashion as that of engineering availability; availability was assigned a value of one (1) and non-availability was assigned a value of zero (0).

The results of this ranking process are synopsized below (see Table 1).

Table 1
Digitizing Table Manufacturer Ranking

Rank	Manufacturer	Basic Table Price	Engineering Availability	Sample Rate	Back-lighting	Weighted Total
1	Altek	1	1	0.91	1	3.91
2	Summagraphics	0.94	1	0.91	1	3.85
3	GTCO	0.76	1	0.45	1	3.21
4	Talos	0.93	0	0.91	1	2.84
5	Aristographics	0.81	0	1.45	0	2.26

Rank - 1 Altek
2 Summagraphics
3 GTCO
4 Talos
5 Aristographics

NOTE: If Interface Electronics, Inc. provides the same tables and services to users that Data Automation previously provided, their ranking would fall with the top two tables denoted above.

4. IMPLICATIONS FOR FURTHER RESEARCH

Questions were raised during the performance period of the effort regarding the value of continued development of the Scanning Cursor, the applicability of the existing scanning cursor in a production environment, the availability of a commercial off-the-shelf scanning cursor, and the need for an area array over the current lineal array used in the scanning cursor.

It is apparent that the availability of a commercial scanning cursor may not be a reality in the near future. Since the scanning cursor concept is the most viable method available to greatly increase data capture rates, it is logical to continue the development of the scanning cursor. This development should involve the areas of Back Light Effects, Scanning Cursor Experiments, and Area Array Study.

The analysis portion of the effort revolving around the topic of back-light effects determined that, although a flicker-free light source is required by the lineal array in the scanning cursor, no best method of providing this light source has been determined. Some of the vendors offered recommendations regarding topics such as DC excitation.

The overall implications of these factors results in Synectics recommending that a small study be undertaken to evaluate the effects of a high frequency fluorescent backlight on the scanning cursor array. This study should also determine the effect (if any) of the high frequency excitation on the lifespan of the fluorescent tubes as well as measure the radiation emitted from the power supply so to ensure the satisfaction of government specifications. A cost effective procedure would be to perform the experiments on a small table rather than the 42" x 60" (1067mm x 1524mm) table.

The recommendation of engaging in Scanning Cursor Experiments would utilize available hardware and software to streamline and expand the functional capabilities of the reflective scanning cursor. DMAHTC has a reflective scanning cursor which is not being used; we recommend that it be acquired by RADC and integrated into the Data General (DG) S/130 of the Geographical Data Processing System (GDPS) of RADC's Experimental Cartographic Facility (ECF). This action would allow the software to be streamlined and the remaining "bugs" to be removed. Use of a higher order language would facilitate modification of the software and/or transferral to another system. [The software modifications would include the capability to compensate for a physical rotation of the cursor. See Section 4.2 of the Final Technical Report for a delineation.]

The experiments would also include the development of a low noise analyzer to provide noise suppression and would incorporate a CRT to monitor the array output. Experiments with the controller (using the S/130 software) would save table points and array outputs on disk. This would enable a review of the discrepancies between digitized data and the source resulting in a distinct pinpointing of the cause of the discrepancy.

The testing of the scanning cursor at RADC has distinct advantages. The existing digitizing table meets the requirements of the reflective scanning cursor. More importantly, arrangements can easily be made to ensure the system's availability for testing and engineering modification.

A final comment regarding implications for further research is that a feasibility study to evaluate the effects of an area array on the scanning cursor concept (as opposed to the use of a lineal array) should be performed. Such an alteration would serve the purpose of removing any mechanical devices. However, four areas of interest

a. increased scan times;

b. effects of fluorescent light on the array;

c. increased processor requirements for accurate handling of the [expanded] data loads; and

d. requirements of the noise analyzer to balance the array output

must be reviewed and evaluated.

The research endeavors delineated above would yield a more productive and responsive Scanning Cursor System without extensive financial expenditures. A parallel review of future requirements and the scanning cursor impact should be performed. Resultant implications regarding cartographic data conversion would greatly enhance the extensive program of automation in the field of cartography.

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1.1 INTRODUCTION

In support of Rome Air Development Center's (RADC's) program to enhance automation in the cartographic field, Synectics Corporation undertook the Scanning Cursor Adaptability effort; a project to determine the adaptability of the scanning cursor to various commercially available opaque and back-lighted digitizing devices. The effort included research of the variety of digitizing devices and determination of pertinent physical and electronic characteristics necessary to interface a scanning cursor to the devices. The devices with suitable characteristics were chosen for design analysis of the necessary scanning cursor hardware and electronic interface. There were no required software modifications. Synectics Corporation utilized the services of RCA (subcontractor status) to perform a portion of the analyses involved. The RCA Advanced Technology Laboratories, Government Systems Division of Camden, New Jersey was the specific subcontractor to Synectics Corporation.

1.2 BACKGROUND

Synectics Corporation, under contract to Rome Air Development Center (RADC) has completed the Scanning Cursor Adaptability effort. This final technical report is in accordance with the requirements (CDRL item A002) and terms of RADC contract F30602-80-C-0072 including the referenced authority data item DI-S-3591A/M and MIL-STD-847A. The final technical report provides data regarding the review of automated cartographic and scanning cursor programs, digitizing device vendors, the analysis of interface requirements, and recommendations and conclusions.

1.3 PURPOSE

The purpose of this document is three-fold. The first is to present an account of the review process; the second is to delineate the considerations which were involved and the interface requirements which were determined. The third and final purpose is to provide the resulting recommendations and conclusions of the Scanning Cursor Adaptability Study to RADC.

1.4 REPORT ORGANIZATION

This document is organized into four areas. Section one presents an overview of the document. Section two "Program Review and Vendor Selection Process" presents automated cartographic and scanning cursor programs which are currently operational or under active development. The programs examined in Section Two were specified by the RADC project engineer. Also presented in Section Two are the details of the digitizing table vendor selection process. The "Analysis of Hardware Interface Requirements", Section Three, contains data regarding: time stream and spatial grid encoding comparison; output data synchronization; array scan displacement error interface; interface selection; and back illumination. The fourth and final section "Recommendations and Conclusions" contains the results of the analyses performed during the effort.

SECTION 2. PROGRAM REVIEW AND VENDOR SELECTION PROCESS

2.1 AUTOMATED CARTOGRAPHIC PROGRAMS

This subsection reviews the procedures and methodology relative to the current digitizing techniques and feature identification procedures in use at Defense Mapping Agency (DMA) Production Centers and in development. As directed by the RADC Engineer for the Scanning Cursor Adaptability project, three pertinent cartographic data acquisition and processing systems were considered in compiling data for this review. These systems were: the Bathymetric Data Reduction System (BDRS); the Advanced Cartographic Data Digitizing System (ACDDS); and the Lineal Input System (LIS). The BDRS and LIS are both on-line production systems with the ACDDS currently under development.

2.1.1 Hardware Configurations

The review of current input procedures encompassed the overall hardware configurations, functional capabilities, specific input processes, and digitizing capabilities of the three comparison systems considered.

2.1.1.1 BDRS. The hardware configuration for this system is illustrated in Figure 2-1. A listing of the major components of this system is contained in Table 2-1. The system is based on the Data General ECLIPSE C300 Processor and uses Data Automation digitizing tables with standard and special cursors, keyboards, and a voice terminal for data entry.

2.1.1.2 ACDDS. The ACDDS, currently under development, is also based on Data General Processors, but uses ALTEK Corporation's backlighted digitizing tables. Data entry is effected by standard cursor, scanning (tracking) cursor, and voice entry. In addition each work station has a CRT with moveable keyboard that can be placed upon the digitizing table to aid in data entry. General configuration for the host system and satellite stations is illustrated in Figures 2-2, 2-3, and 2-4. A component listing is provided in Table 2-2.

2.1.1.3 LIS. The Lineal Input System is a Digital Equipment Corporation processor based system, utilizing Gradicon digitizers and Imlac computers at individual work stations. Data entry devices include a portable CRT keyboard, a special function keyboard, and a standard free cursor. Figure 2-5 depicts the basic hardware configuration for the LIS, with Table 2-3 listing specific components.

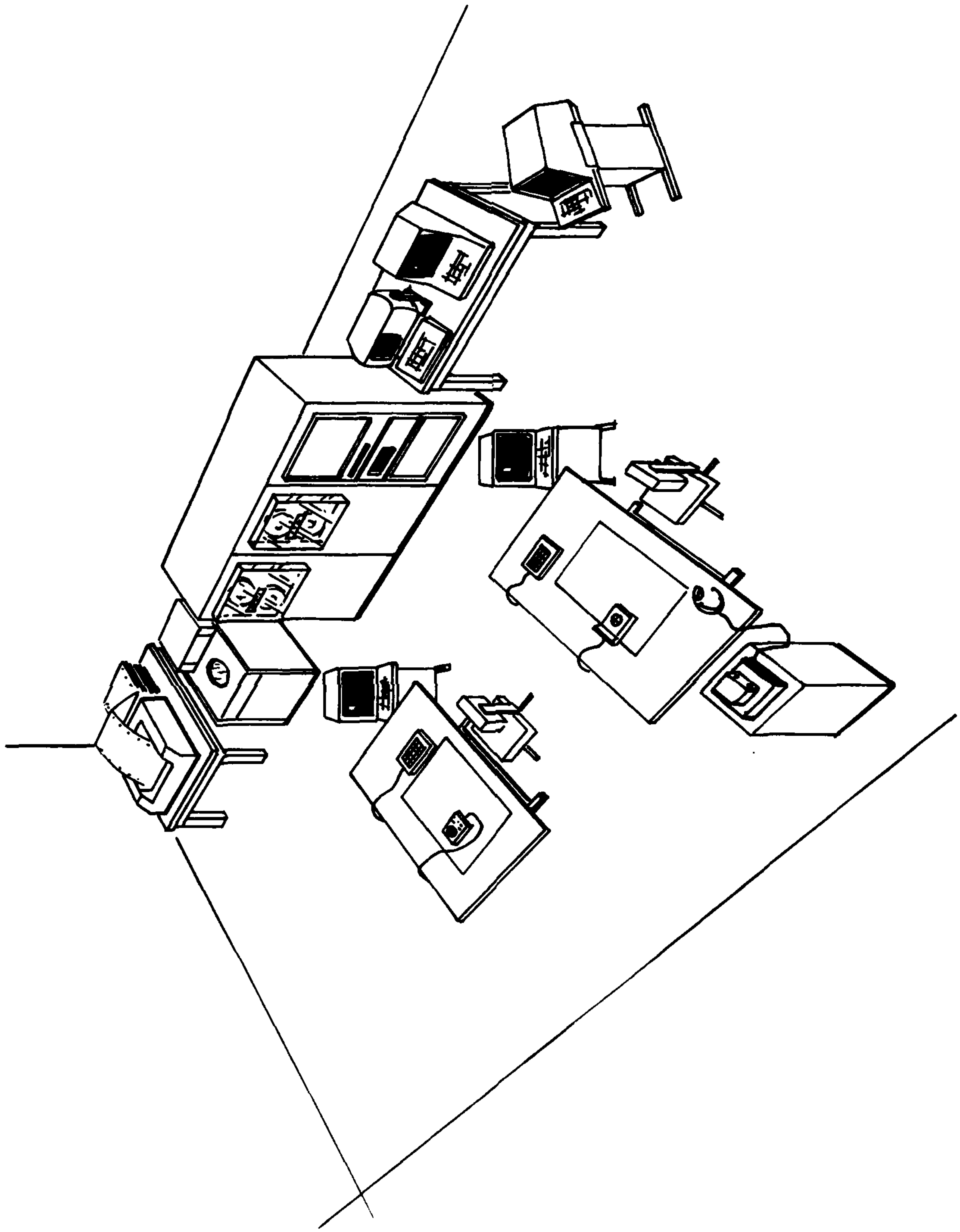

Figure 2-1. BDRS Hardware Configuration

Table 2-1

BDRS Hardware Components

COMPONENT	MANUFACTURER					SUBSYSTEM			
	Data General	Data Automation	Tektronix	Centronics	Threshold Technology	Host	Workstation 1	Workstation 2	Total
ECLIPSE C300 CPU	✓					1			1
Magnetic Tape Units	✓					2			2
CRT 6012	✓					1			1
Line Printer				✓		1			1
Disk Drive 92 MB	✓					1			1
Digitizing Tables		✓					1	1	2
Graphic Terminal 4010			✓				1	1	2
CRT 6052	✓					1			1
Graphic Terminal 4014			✓			1			1
Standard Cursor		✓					1		1
Display Cursor		✓						1	1
16 Key Keyboard							1	1	2
Voice Data Entry Terminal					✓			1	1

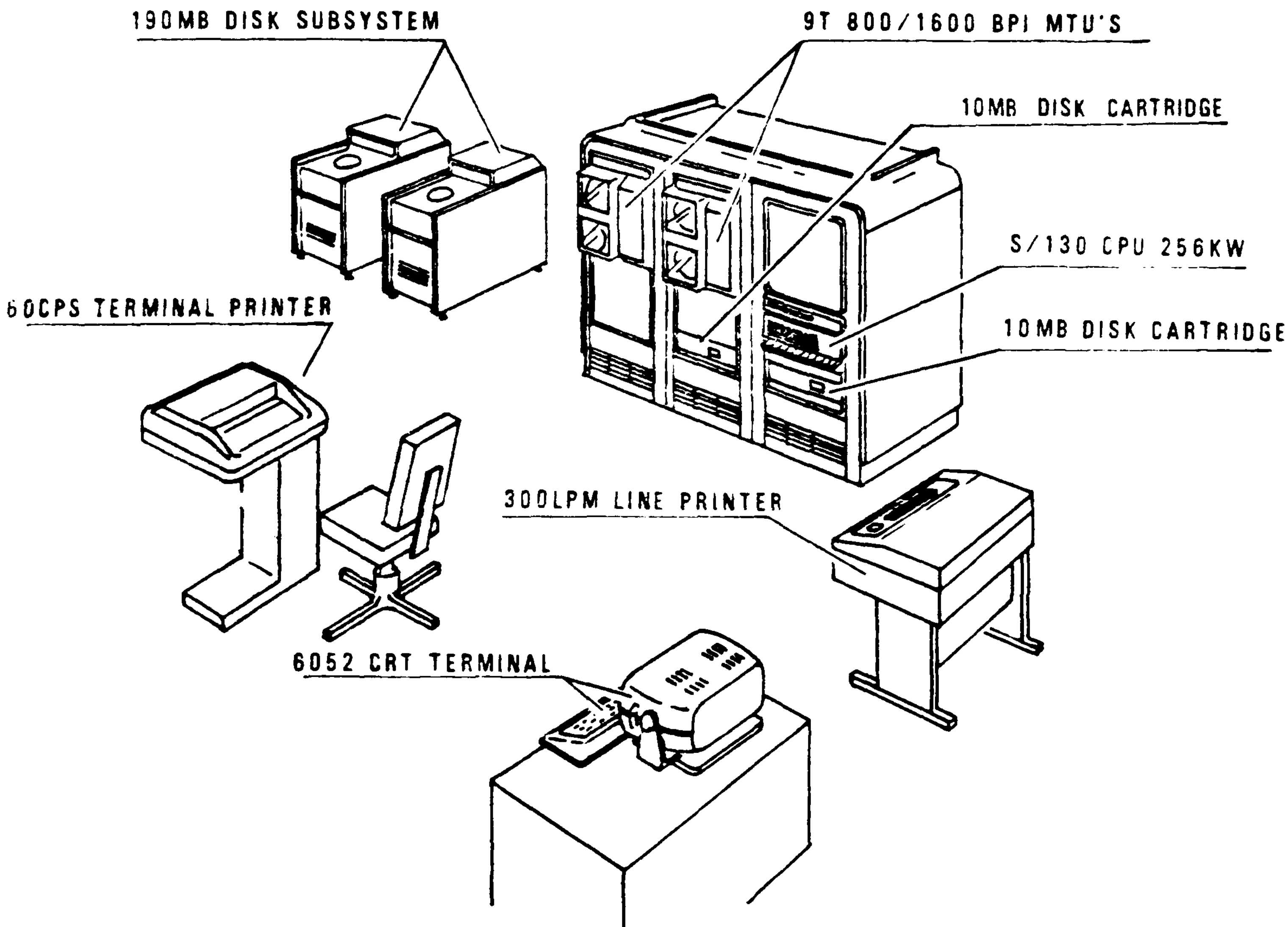

Figure 2-2. ACDDS Host Processor Hardware Configuration

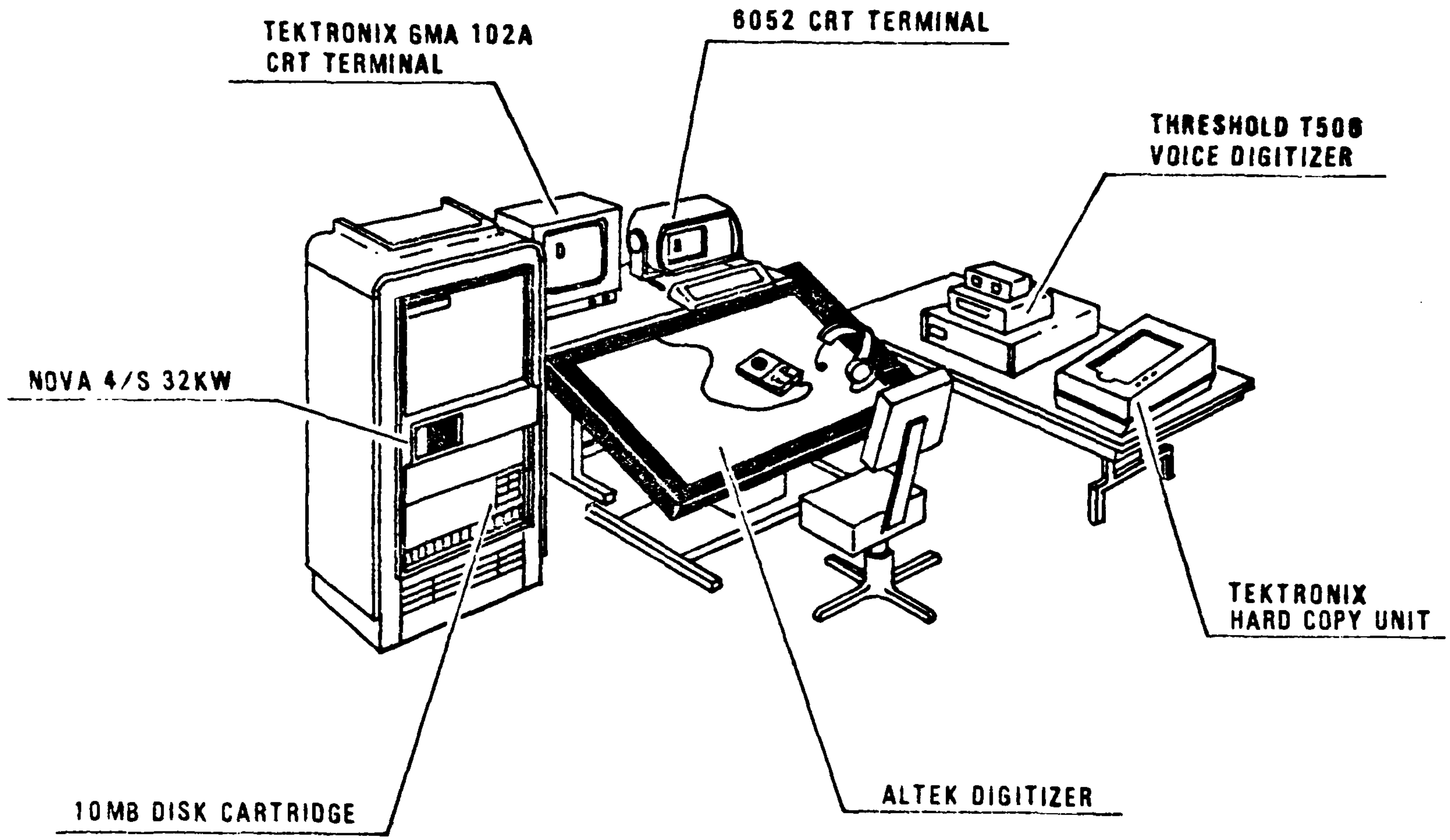

Figure 2-3. ACDDS - Computer Assisted Satellite Station

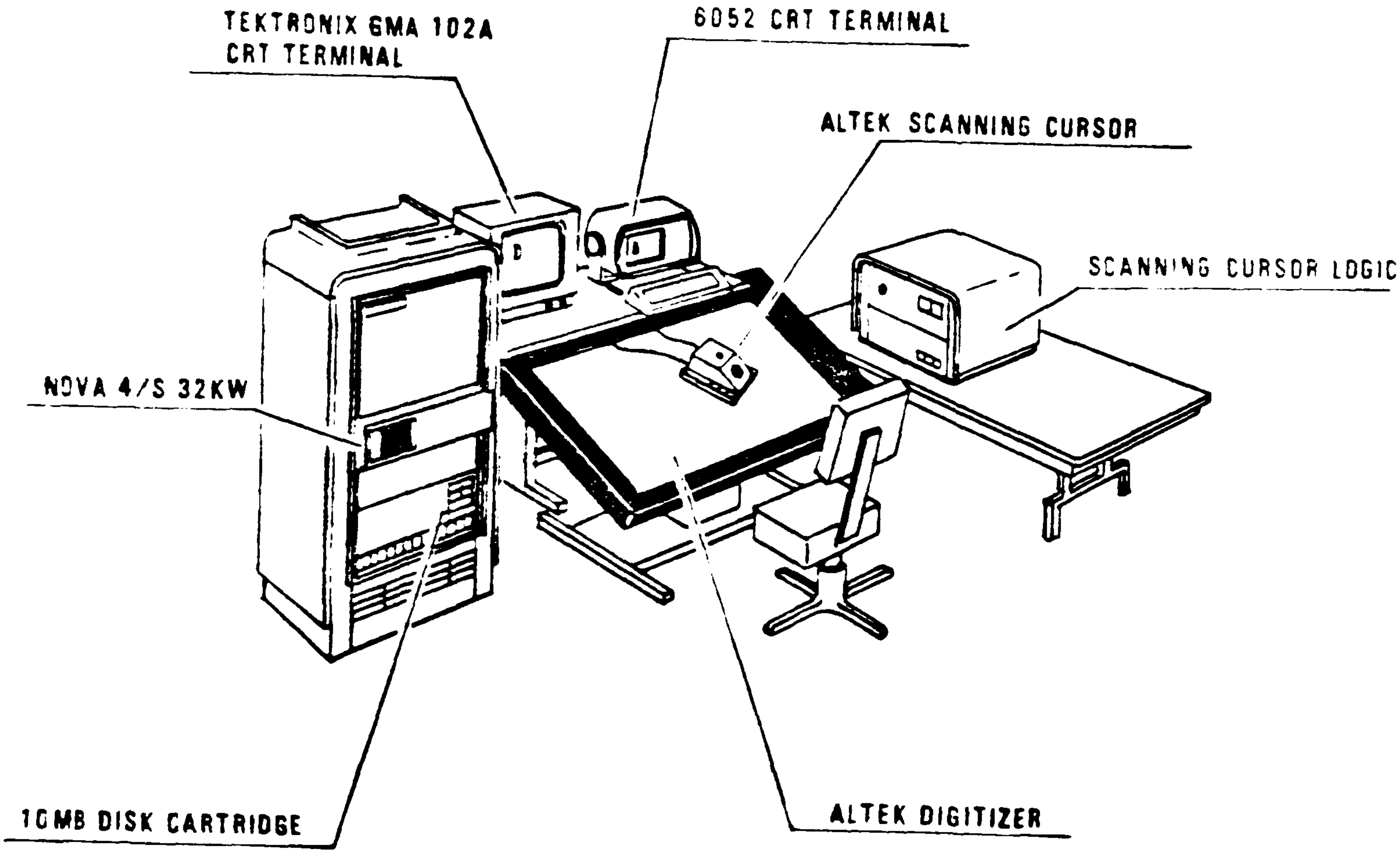

Figure 2-4. ACDDS - Computer Assisted Trace Satellite Work Station

Table 2-2

ACDDS Hardware Components

COMPONENT	MANUFACTURER				SUBSYSTEM				
	Data General	Altek Corporation	Tektronix	Threshold Technology	Host	Workstation 1	Workstation 2	Workstation 3	Total
ECLIPSE S/130 CPU	✓				1				1
NOVA 4/S Computer	✓					1	1	1	3
60 CPS Terminal Printer	✓				1				1
Video Display Term. 6052	✓				1	1	1	1	4
Magnetic Tape Units	✓				2				2
Disk drives, 190 MB	✓				2				2
Cartridge Disk, 10 MB	✓				1	1	1	1	4
Line Printer, 300 LPM	✓				1				1
Digitizing Tables		✓				1	1	1	3
Standard Cursor		✓				1			1
Scanning Cursor		✓					1	1	2
Voice Entry Terminal				✓		1			1
GMA 102A Graphic CRT			✓			1	1	1	3
Hardcopy Unit			✓			1			1

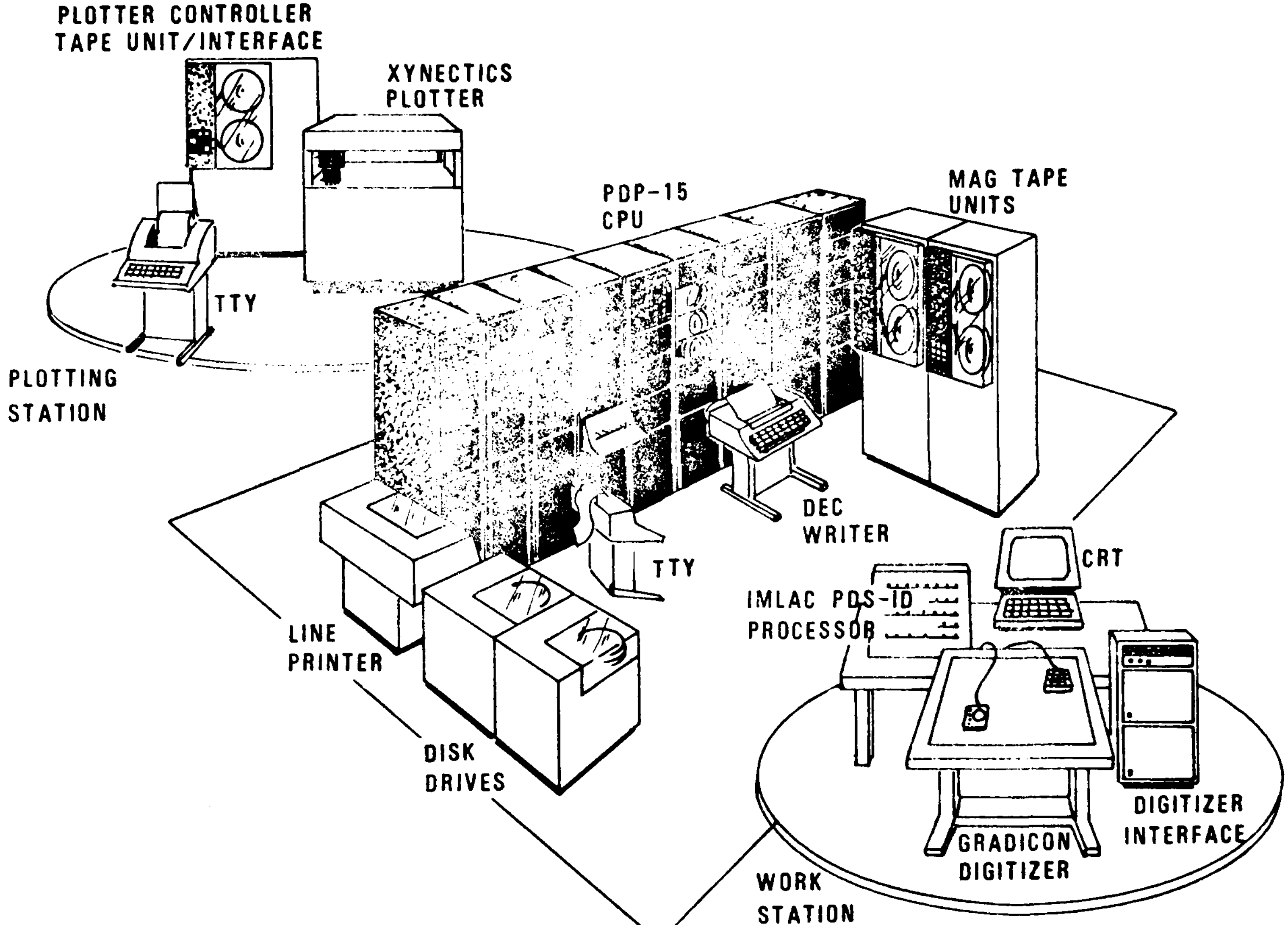

Figure 2-5. Basic LIS Configuration

Table 2-3

Basic LIS Hardware Components

	MANUFACTURER					SUBSYSTEM			
	DIGITAL EQUIPMENT CORP.	IMLAC CORPORATION	GRADICON CORPORATION	TELETYPE CORPORATION	XYNETICS CORPORATION	HOST	WORKSTATIONS (1)	PLOTTING STATION	TOTAL
PDP-15-CPU	✓					1			1
PDS-1D PROCESSOR		✓					1		
MAGNETIC TAPE UNITS	✓					3			3
LOG TELETYPE	✓					1			1
COMMAND TELETYPE				✓		1		1	2
VIDEO DISPLAY CRT							1		1
DIGITIZING TABLES			✓				1		1
LINE PRINTER	✓					1			1
DISK DRIVES	✓					2			2
PLOTTER (W/Processor & Tape Unit)					✓			1	1
FIXED HEAD DISK	✓					2			2

2.1.2 Functional Capabilities

2.1.2.1 Data bases. A brief overview as to the content and/or structure of the data files for each of the three systems reviewed is presented in the following paragraphs.

a. BDRS. The BDRS Master Mode software controls the operational environment of the BDRS Data Base. Physical deletion of a file as well as user access is controlled by the Master Mode operation. The architecture is comprised of a single task using six overlays. Each function defined by its separate overlay is loaded from disk when called by the Executive routine. All three subsystems of the BDRS produce and process files. The digitizing process produces four unique table files: header; index; data; and fathogram (when a fathogram is digitized). Batch processes produce table and geographic files. The Data Base creates and uses geographic files. In addition to files, there exist document and source description records which are essential to the Data Base. The document and source description record is used to describe each document that is loaded into the Data Base. For every document there can be only one document description record. The source description record gives more information about the file that has been digitized. There can be more than one source description record for a document.

b. ACDDS. The ACDDS data file structure pertinent to interfacing with external systems consists of a set of files labeled: Feature Table Data File; Grid Feature Index File; Feature Identification File; Working Header File; and Feature Geographic Data File. The Table Data File contains feature data sets encompassing a feature header record and feature textual record followed by "N" data blocks used to hold the digital description of the feature. The feature may contain trace data, discrete point data, or sounding data. The Grid Feature Index File contains pointers to feature header records and data records. Predefined one inch squares of the digitizing table define a random record pointer into the grid file. Each grid index record contains all feature header and data random record pointers that enter that particular grid square. Each grid record has the capacity to hold thirty-one feature header record and data record pointers with overflow provisions to provide virtually unlimited capacity. The Feature Identification File contains header record pointers to features which correspond to that feature's identification record length. This file is primarily used by the feature edit function to retrieve a feature by I. D. number. The Working Header File consists of headers chosen by the operator during session start-up. Headers are extracted from a master catalog library stored on disk, and included into the job working header set. The file may be updated at any time during a work session and each time a new permanent header is created/selected from the master, it is appended to the header file. The Geographic Data File is comprised of 64 word records, of which, records one through ten contain parameter blocks one through three, registration blocks one through six, section/panel record, and commentary blocks. These ten blocks are the Parameter Control File. The subsequent records are comprised of feature sets. Each set contains an ACDDS geographic header block and texture header block followed by geographic data records.

c. LIS. The master processor software of the LIS consists of three primary areas: the Executive; the Data Access Module (DAM); and the Batch Programs. The Executive is tasked with managing system resources, handling input and output to the peripheral devices, and dispatching control to system programs as required. Through its appendage, the job stream monitor/job stream dispatcher, the execution and rollover of batch programs are initiated and monitored. The DAM is the LIS data management subsystem and it performs all tasks, as needed, to allocate disk memory (dynamically), to store features, to create X-Y retrieval indices, and to retrieve feature data. Its most critical programs are core resident, with the balance being rolled into core as required. Major functions provided by the DAM include: storage of features in data files by their sequence number; creation of a positive index for stored features through which a feature may be retrieved based on its proximity to a given coordinate value; allocation of disk memory to individual files as the files grow and require additional space; performance of maintenance functions such as file status reports, open and close files, and delete files; retrieval of features within a file based upon feature sequence number, feature data disk address, closest feature to a specified coordinate value, feature passing within a specified threshold distance from a designated point, closest feature (within a grid) to a designated point but excluding a specified feature; and closes point on a designated feature to a specified point.

2.1.2.2 Batch programs. Comparable Batch Processing capabilities of the three systems being considered are listed in Table 2-4. Of the total of fifteen functions listed, the three systems have similar batch capabilities in seven areas. The ACDDS and LIS systems have a total of thirteen comparable functions while the BDRS and ACDDS have a total of eight comparable batch processing functions. A batch program that is unique to only one system (ACDDS) is that of Digital Orthorectification.

2.1.2.3 Operational/utility software. Of the eleven Utilities Functions listed in Table 2-5, the ACDDS and LIS are comparable in all eleven functions, while the BDRS is comparable in all but three functions. These functions being: Hardcopy Log Maintenance; System Status Summary; and Job Stream Status Monitor Report.

2.1.3 Input Processes

2.1.3.1 Hardware configuration. All three systems (BDRS/ACDDS/LIS) utilize a free cursor of relatively standard design, with push-button command control for feature data acquisition, feature retrieval, and editing functions (See Figure 2-6). The BDRS and the LIS utilize special purpose keyboards for purposes such as the entering of sounding values or discrete points (BDRS) (See Figure 2-7), joining features, modifying segments, deleting features, etc., (LIS) (See Figure 2-8). The BDRS and ACDDS employ a voice recognition/digitizing device for recording soundings (depth data) (BDRS) (See Figure 2-9). The BDRS employs at one workstation a special display cursor that operates in the same fashion as a standard cursor but provides a digital read-out via a built in LED display panel (See Figure 2-10). A tracking cursor is employed by the ACDDS which provides the same functions as a standard table cursor but allows the operator to deviate from the time track of a feature while the device logic corrects X-Y coordinate, resulting in increased digitizing rates and lessening of operator fatigue. Text data, parameter definition, header build data, and similar data input is effected through CRT keyboards (either fixed or floating for all three systems). Types of generic hardware input devices used by each system are listed in Table 2-6.

2.1.3.2 Digitizing capabilities and procedures. All three systems share practically equal capability of basic digitizing functions such as lineal trace and point data entry; the major difference being the lack of depth entry mode in the LIS. A capability comparison is indicated in Table 2-7. Specific data entries required for the three systems are compared in Figures 2-11 through 2-15. There are some nomenclature sequencing anomalies existing in the specified data entry steps presented in these work flow charts. However, the basic data

Table 2-4

Batch Processing Capabilities

FUNCTION	BDRS	ACDDS	LIS	REMARKS
Mag Tape to Disk	X	X	X	
Filtering, Inclusively/ Exclusively		X	X	
Sort and Merge		X	X	
Format Conversion	X	X	X	
Unit Conversion	X	X	X	
Projection Transformation	X	X	X	
Sectioning (Table)		X	X	
Sectioning (Geo)	X	X	X	
Paneling (Table)		X	X	
Paneling (Geo)		X	X	
Symbolization		X	X	
Plot (Xynetics)	X	X	X	
Plot (Calcomp)	X	X		
Reporting	X	X	X	
Digital Orthorectification		X		

Table 2-5

System Utilities

FUNCTION	BDRS	ACDDS	LIS	REMARKS
Maintain Hardcopy Log		X	X	
System Status Summary		X	X	
Mag Tape Formatter	X	X	X	
Job Stream Status Monitor Report		X	X	
File Directory Report	X	X	X	
Print Control Information	X	X	X	
File Summary	X	X	X	
Peripheral Diagnostics	X	X	X	
Digitizing/Edit Station Diagnostics	X	X	X	
Storage Status	X	X	X	
Disk to Tape	X	X	X	

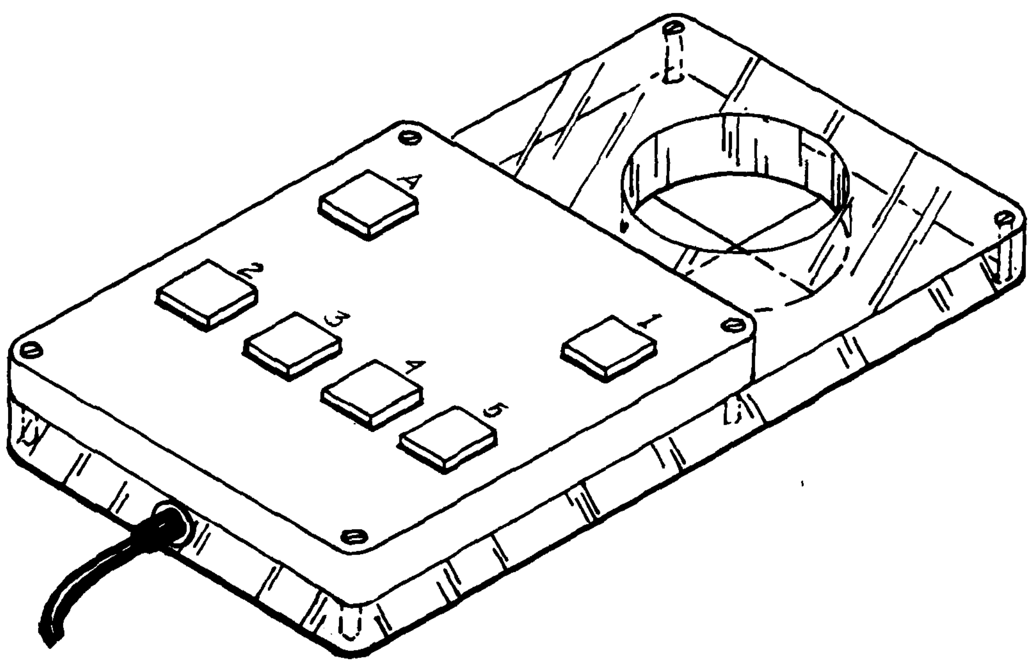

Figure 2-6. Typical Standard Free Cursor

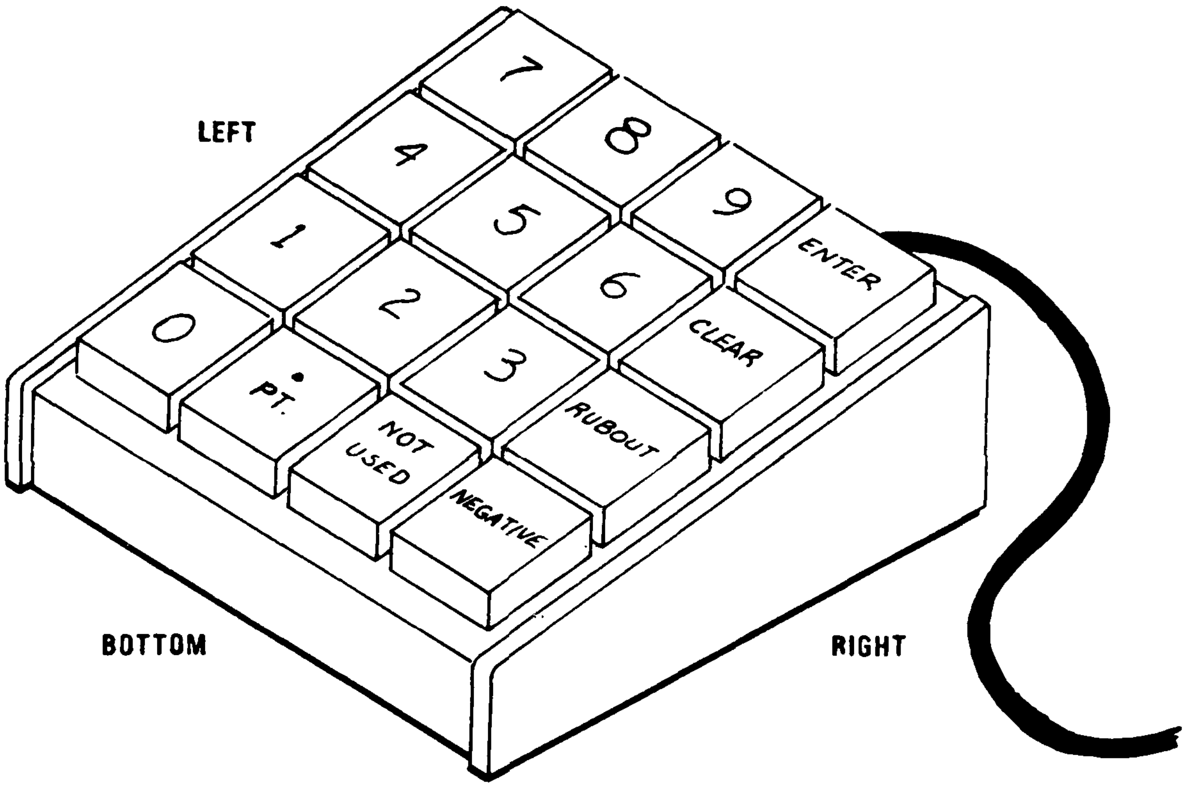

Figure 2-7. 16-Key Keyboard Layout

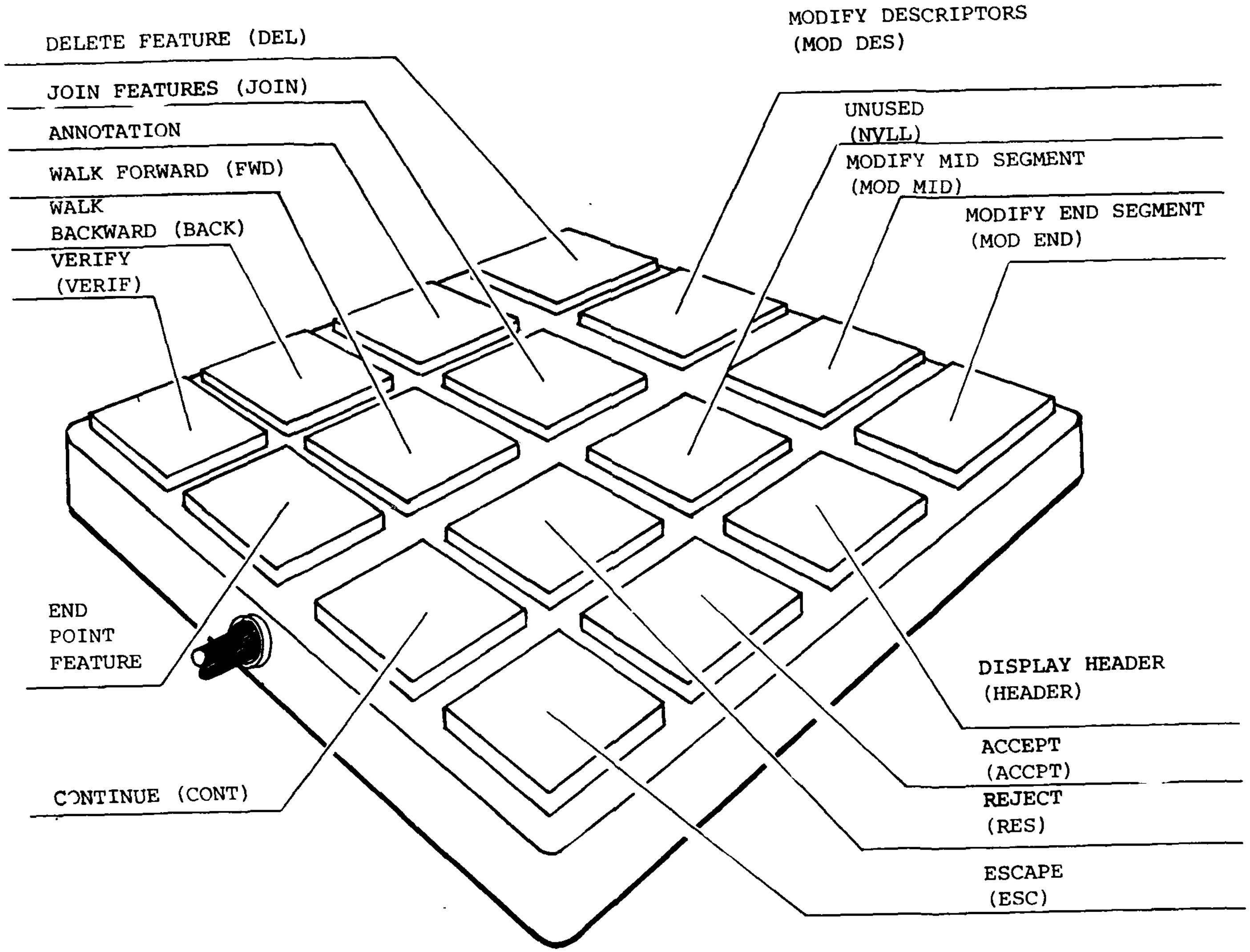

Figure 2-8. LIS Special Function Keyboard

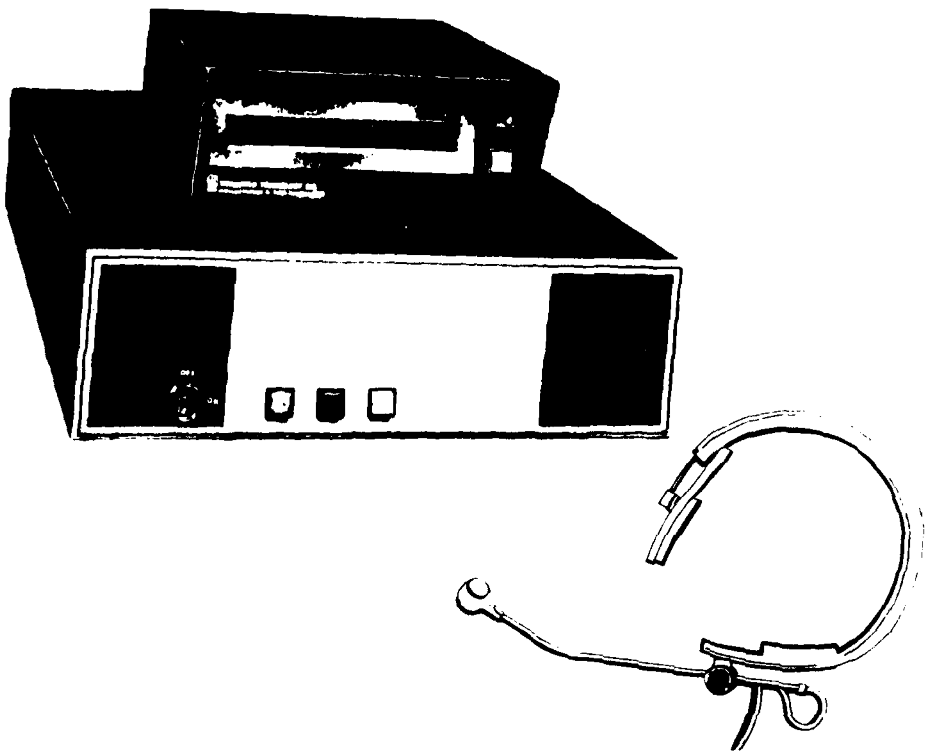

Figure 2-9. Voice Data Entry Device

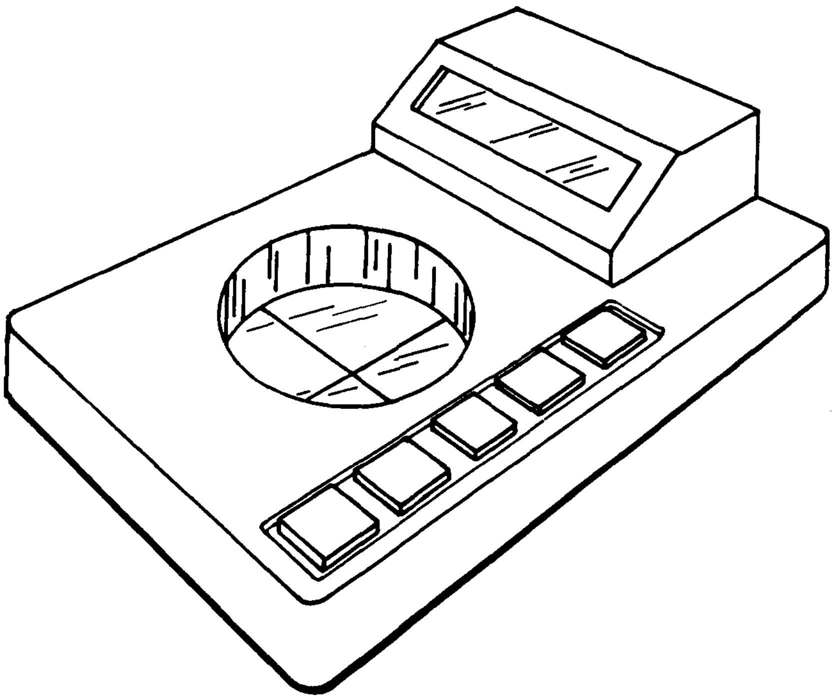

Figure 2-10. BDRS Display Cursor

Table 2-6

Input Hardware Devices

	BDRS	ACDDS	LIS	REMARKS
Feature Data Acquisition	----	----	----	
Standard Free Cursor	Yes	Yes	Yes	
Display Cursor	Yes	No	No	
Tracking Cursor	No	Yes	No**	See Below
Special Keyboard	Yes	No	Yes	
Voice Data Entry Device	Yes	Yes	No	
Text Data Entry	----	----	----	
Keyboard (Fixed)	Yes	No	No	
Keyboard (Floating)	No	Yes	Yes	

*LIS has been equipped with an RCA Prototype of a computer assisted Trace functioning cursor, however it is not used in production

Table 2-7

Digitization Capabilities

FUNCTION	BDRS	ACDDS	LIS	REMARKS
Continuous Trace	Yes	Yes	Yes	
Point to Point	Yes	Yes	Yes	
Continuous to Point	Yes	Yes	Yes	
Type 1 Edit		Yes	Yes	
Fathogram	Yes			
Depth Entry (Manual)	Yes	Yes		
Depth Entry (Voice)	Yes	Yes		
Depth Data Delete	Yes	Yes		
Discrete Point Entry (Manual)	Yes	Yes	Yes	
Discrete Point Entry (Comp-Assist		Yes	*	See Below
Discrete Point Data Deletion	Yes	Yes	Yes	
Review-Display Area	Yes	Yes	Yes	
Review-Scale Change	Yes	Yes		
Review-Filter		Yes		

* LIS equipped w/prototype C. A. Cursor, but not used.

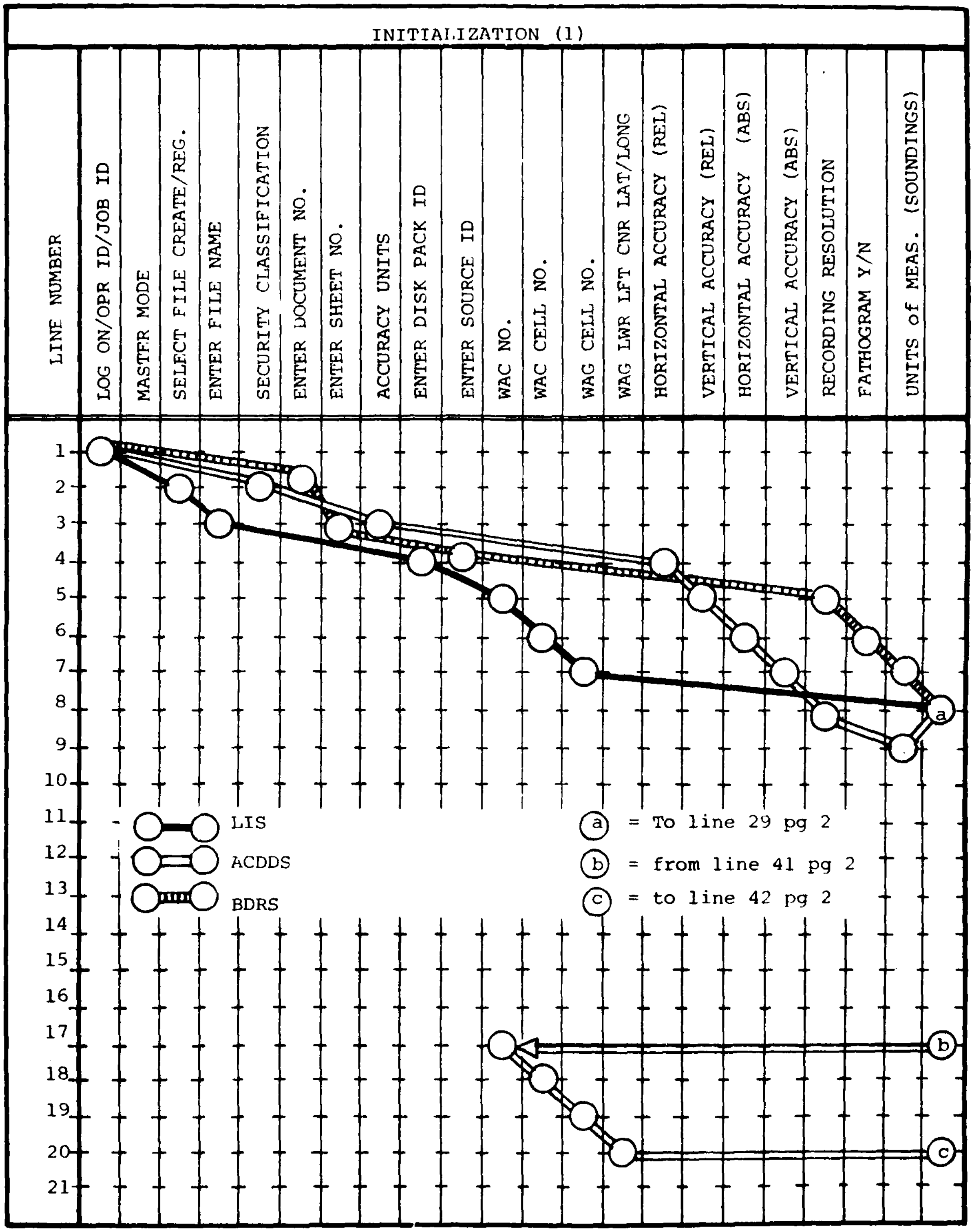

Figure 2-11. Initialization Procedures (1) Page 1

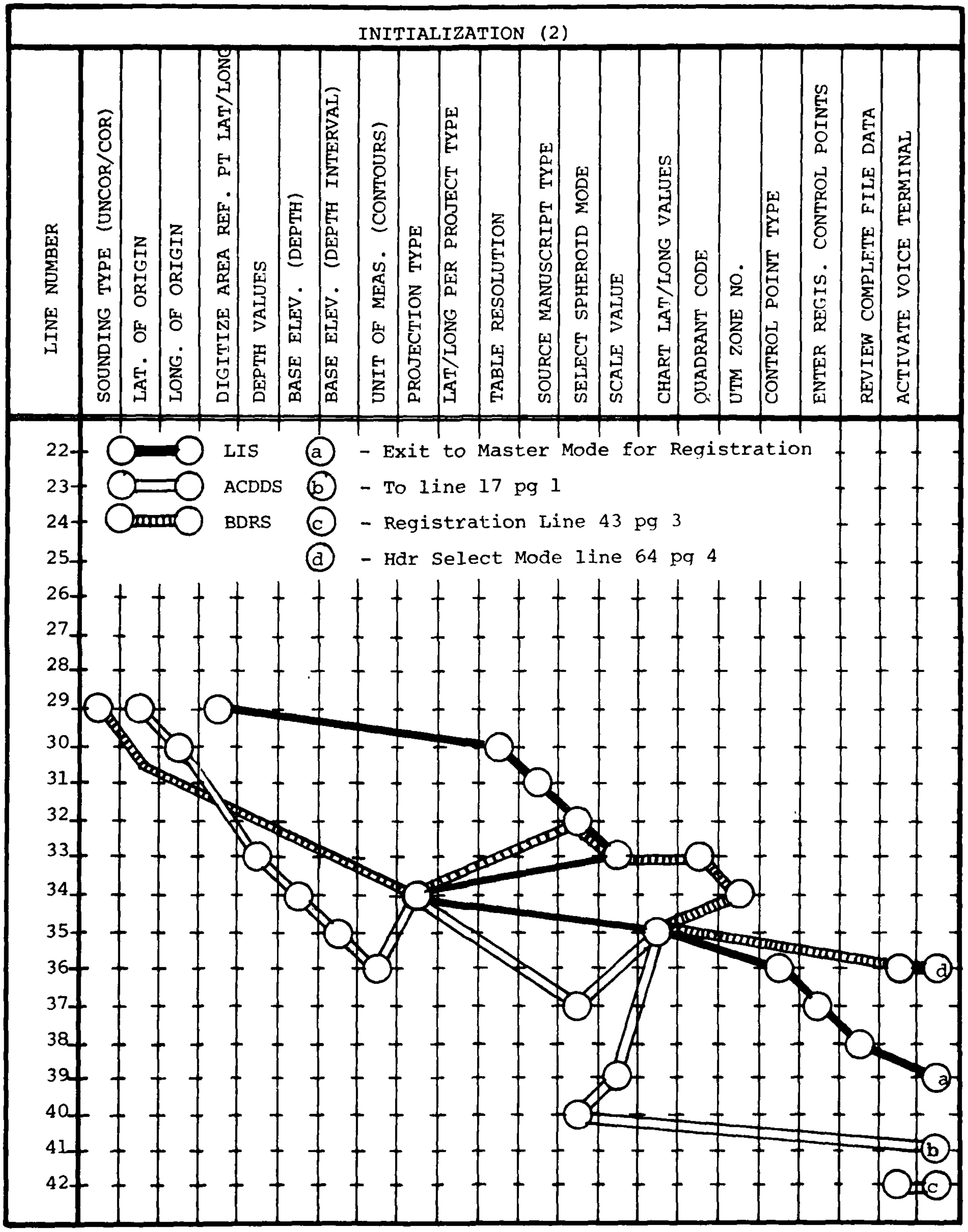

Figure 2-12. Initialization Procedures (2) Page 2

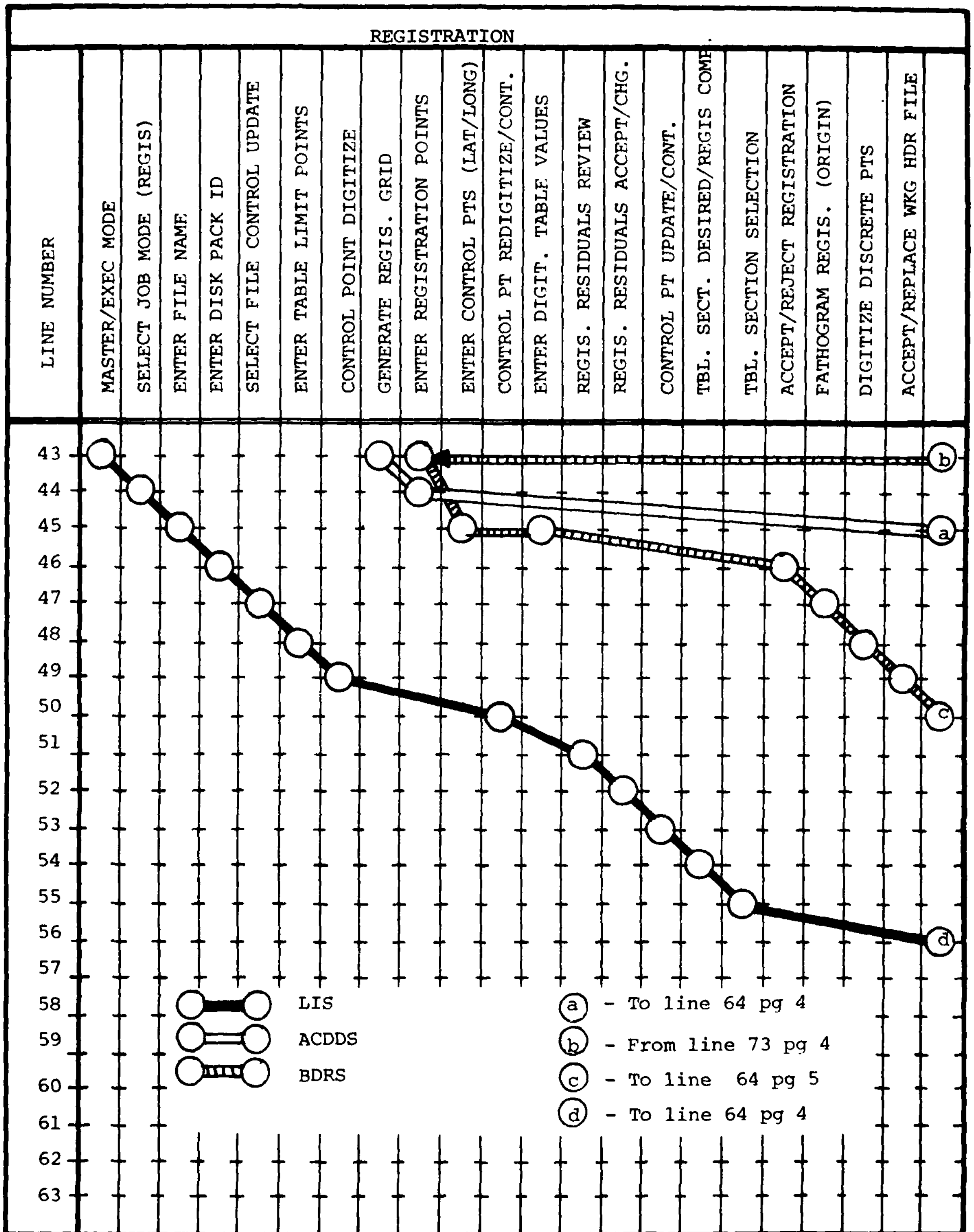

Figure 2-13. Registration Procedure

Page 3

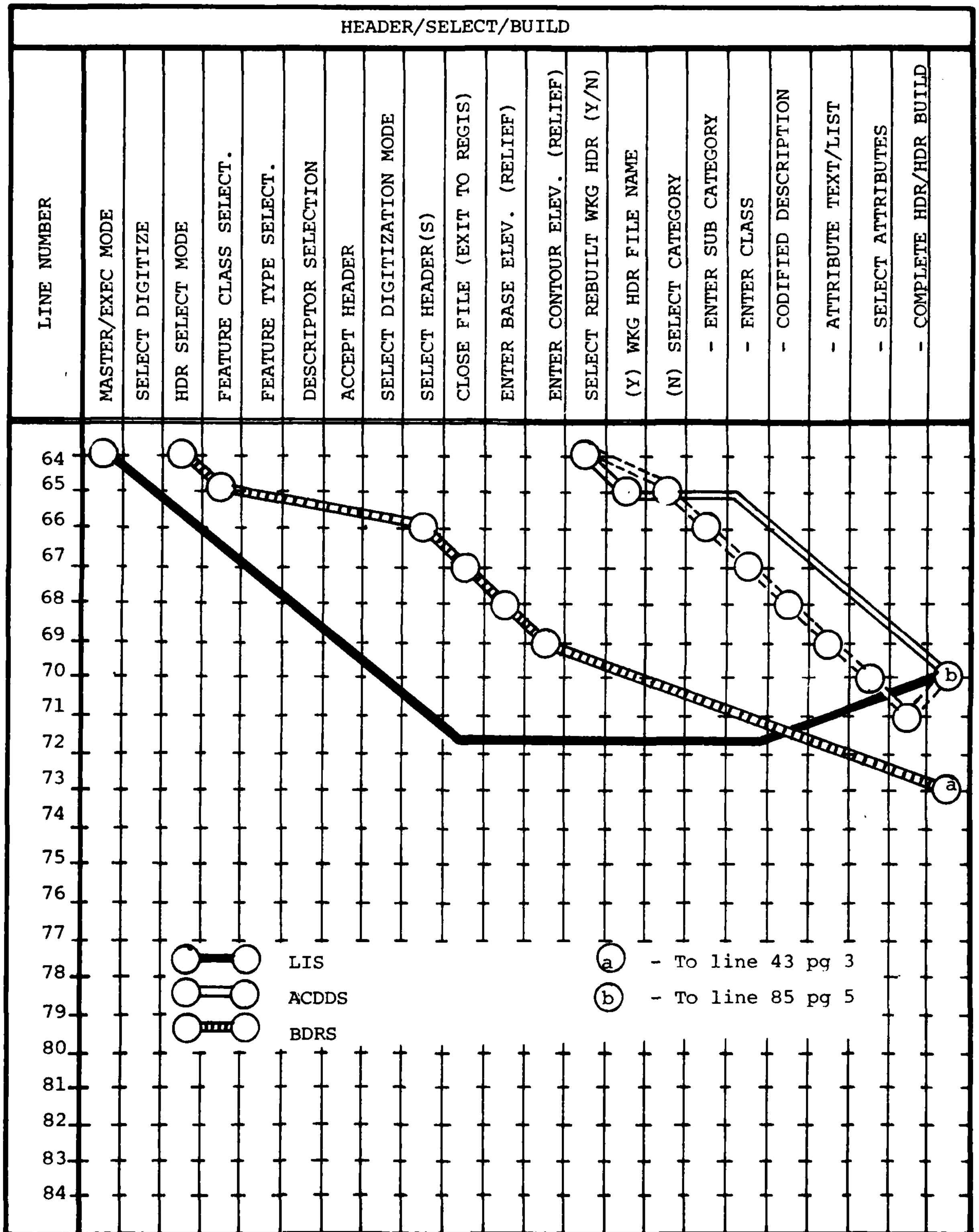

Figure 2-14. Header Select/Build Procedure

Page 4

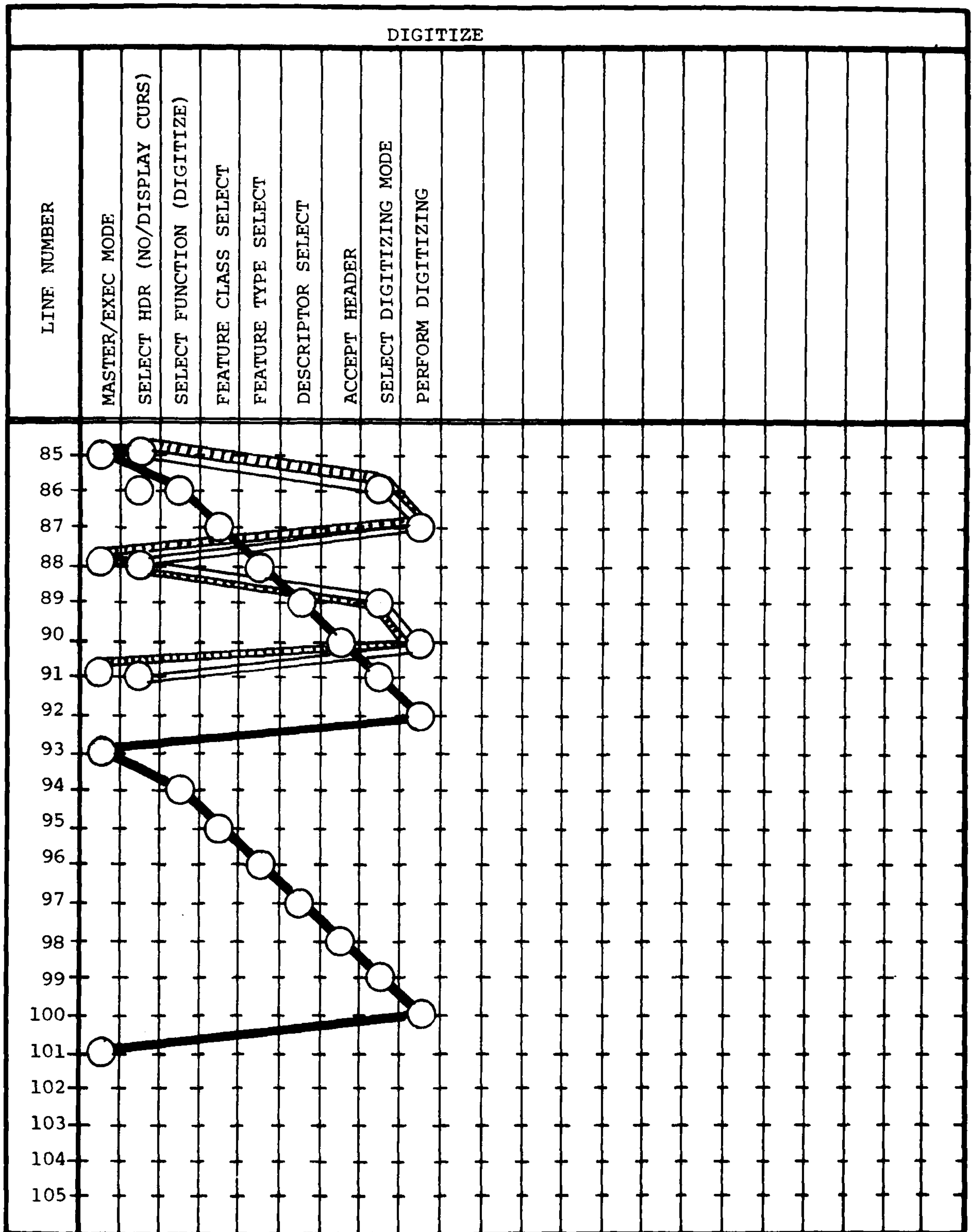

Figure 2-15. Digitization Procedures Page 5

entries required for bringing a digitizing work station from "Log-On" to preparation for a second feature digitization session are represented. It is also to be noted that within these data entries there are further variations in the number and type of actions required to complete that entry.

In comparing the three systems it is found that the ACDDS, using its pre-built header capability, has substantially fewer entries to make (34) versus the LIS entry count of 47. The primary reason for this being the necessity of rebuilding a header for each change of feature to be digitized. The BDRS is very close to the ACDDS, with a total of 36 entries. The fewer number of entries is further noteworthy when consideration is made of the additional capability of both the ACDDS and BDRS for depth data recording and Voice Terminal Operation.

2.1.3.3 Source data. The primary source of data for which all three of the systems under consideration were initially designed and developed is that of analog graphics. Three items are represented by maps, charts, fathograms, random track data, survey track data, smooth sheets, special graphics, and others.

A salient feature of the ACDDS not present in the other systems is the digital orthorectification capability which provides for photo source digitization and output as table data which can be converted to geographics via a batch transformation function.

2.1.4 Feature Description Standards

The standardization of map features to facilitate exchange of digital cartographic data between the DMA production centers was the basis of an effort performed by the Ad Hoc Study Group on Map Feature Standardization. This effort resulted in the defining, coding, and cataloging of map features and the establishment of the DMA Standard Cartographic Feature Digital Data File. In furthering the concept of numerically coded standard cartographic features, primary emphasis was placed upon the efficient storage, retrieval, and exchange of digital map/chart cartographic feature data and future incorporation of special purpose, digital products produced by the DMA production centers.

A hierarchical scheme was developed to facilitate the assignment of a feature to an element of the hierarchical tree and to minimize the length of standard data code. This scheme permits future introduction of new features into the proper category. The concept developed was based upon an assignment of a unique four-digit numeric designation for every feature, facilitating computer searches of digital files. Feature attributes (modifiers) were also codified with three digit identifiers to permit modification of the four-digit feature identification to include all the possible combinations required for standard maps and charts. This feature identification standard concept is published in the Defense Mapping Agency Standard Cartographic Feature Digital Identification Catalog, July 1977.

The ACDDS uses the DMA Standard Cartographic Feature Digital Data File concept which is based on ten major categories, to establish feature identification. The LIS utilizes an ACS developed feature class definition list of eleven categories. The BDRS was designed to be compatible with the LIS but with added categories for bathymetric data. Table 2-8 lists the category breakdown for each system.

2.1.5 Feature Identification Input and Edit

All three systems use a menu driven format, operator prompt system, to build headers for feature identification for digitizing. The ACDDS normally operates with a pre-built header file; required headers are selected by number prior to feature digitization. The BDRS establishes a header file during the header build mode during session set-up. Headers are selected by positioning a display cursor on the appropriate header while in master mode prior to going to digitization mode. The LIS headers are built or modified each time a new feature is to be digitized.

2.1.6 Header Build Functions

The three systems all have provisions for editing or modifying the header description at various times during a work session.

2.1.6.1 BDRS. The BDRS HEADER mode provides for the selection and/or establishment of headers (identification information) for lineal and discrete points. It also provides for the initiation of output processing options and parameters/condition changes. As it is the central mode of the Digitizing Module, it is entered after completion of any of the other mode processes; e.g., REGISTRATION, TRACE, EDIT, REVIEW, etc. The Header Selection Mode is entered to create a working header set disk file for a new job, or to add or replace an existing job's working header set. The operator is requested to choose any of the available header categories listed on the display screen. The BDRS uses an LIS-compatible header structure with the addition of bathymetric oriented classes, they are the following:

a. Deep Ocean Survey;

b. Deep Ocean Random; and

c. Fathogram.

Table 2-8

Major Feature Categories

BDRS	ACDDS	LIS
(Same as LIS plus the following)	(0) CULTURE (Facilities & Populated Places)	(1) ROADS
COASTAL/HYDRO SURVEY	(1) CULTURE (Transportation)	(2) POPULATED PLACES
COASTAL/HYDRO RANDOM	(2) CULTURE (Delimitors)	(3) RAILROADS
DEEP OCEAN SURVEY	(3) COASTAL HYDROGRAPHY/MARINE DANGERS	(4) CULTURE
DEEP OCEAN RANDOM	(4) INLAND HYDROGRAPHY	(5) BOUNDARIES
FATHOGRAM	(5) HYPSOGRAPHY (and related land forms).	(6) RELIEF
COASTAL/HYDRO RELIEF	(6) MARITIME FEATURES AND NAVIGATION AIDS	(7) DRAINAGE
	(7) VEGETATION	(8) COASTAL HYDROGRAPHY
	(8) AERONAUTICAL FEATURES AND NAVIGATION AIDS	(9) VEGETATION
	(9) RELATED AERO/MARITIME FEATURES AND NAVIGATION AIDS	(10) NAVIGATION AIDS
		(11) PORTS AND HARBORS

Additionally, the LIS category of coastal Hydrography is broken into three categories:

a. Coastal Hydro Survey;

b. Coastal Hydro Random; and

c. Coastal Hydro Relief.

Once a category is selected, a disk file containing the entire library of headers is scanned for headers matching the selected category; these headers are displayed as a page or group of 15 headers. The operator then selects which of the 15 are to be put in the job's working header set by use of the Tektronix thumbwheel-controlled cross-hair cursor, or can advance to the next page of headers as desired. If any relief feature headers are chosen, the operator is requested to enter a signed 5-digit elevation base value and 4-digit contour interval after header selection has been completed.

2.1.6.2 ACDDS. The ACDDS header build function is loaded into memory via the executive function upon completion of the registration function or the selection of this function within the auxiliary function. The header build function is used to generate a set of cartographic header description codes that are applied to feature data sets upon digitization. The operator selects all header descriptor sets that will be applied to the feature headers during a digitizing session. Descriptor codes are selected via operator interaction with the alphanumeric CRT and keyboard (DG-6052). The DMA Standard Cartographic Feature Digital Identification Data file is used to present, in a hierarchical scheme, feature classes; sub-classes; and attributes. From this file the operator selects, in a hierarchical fashion, the feature class followed by the sub-class and attributes associated with that class and sub-class. The user may also enter attributes extracted from the master attribute list. The maximum number of attributes entered may be tweleve while the minimum may be zero. After completion of each entry (class, sub-class, and attributes) these codes are stored into an ASCII file checking for identical header codes. If one is found the one most recently input is deleted. At any time within this function the operator may kill the function; control is then passed to executive mode (no changes are made to the original working header file if updating). The operator may also have displayed the help function to guide the user through the header build process.

2.1.6.3 LIS. The LIS employs a hierarchical feature description scheme developed for the cartographic data base within the ACS. This scheme is flexible in that accurate description of a wide range of feature types is possible; in case new feature types are developed, the scheme permits new permutations of descriptors and new qualifiers to properly describe the new feature type. All features are described initially by the specification of a feature class. Selection of this class is made via a menu on the CRT. Each class selected spawns a feature type selection display appropriate to the selected class. Selection of a feature type results in the display of a "feature subtype" menu from which the operator selects a subtype. Selection of a subtype, in turn, results in the display of a feature descriptor selection menu (or menus) through which specific class/type/subtype-determined variables are entered. Finally, numeric and title fields are filled (e.g., elevation, population, and name), and comments pertinent to the feature or its source representation may be entered. Every feature within the LIS data base has a 256-word feature header containing the descriptor information as entered above. From this header, the LIS enables partitioning of data files into subsets determined by the values of the feature descriptors. In this manner, only selected subsets need be involved in any LIS operation, and LIS output may be readily sorted according to system needs. The operator need not completely respecify a feature header for each feature, since the LIS enables him to change only those parameters altered from the previous feature entered.

2.1.7 Feature Identification Input Procedures

2.1.7.1 BDRS. The BDRS main HEADER mode display consists of instructions, at the top of the display, a "page" of headers from the working header set disk file, and an elevation value. Pages consist of groups of headers from the working header set, up to 15 headers per page. Next, previous, or last page of headers can be accessed through keyboard control. Selection of a feature class (see Figure 2-16) is made by positioning a moveable display screen crosshair (Tektronix thumbwheel control) to the feature class of interest and depressing any character on the keyboard. The next menu (see Figure 2-17) will be displayed. Again header(s) selection is made by positioning the screen crosshair to the desired header and depressing any character. An asterisk will appear between the header and free text of the chosen header (see Figure 2-18). To display the next group of headers the crosshair is positioned on "DISPLAY NEXT GROUP" and depressing any character on the keyboard. The next group of headers will appear on the Tektronix Screen or, if last group, will display the Feature Class menu (Figure 2-16). To close the header selection process, the crosshair is positioned on "CLOSE SELECTION FILE" and any character is depressed. If "RELIEF CLASS" was chosen in a previous selection, the menu as illustrated in Figure 2-19 will appear, otherwise exit is made to "REGISTRATION". When the major class "FATHOGRAM" is selected a menu as illustrated in Figure 2-20 will be displayed.

2.1.7.2 ACDDS. The ACDDS operational scenario calls for the establishment of a "pre-built" set of working headers which can be selected by number at the time of feature digitization. Headers are built using a menu prompt format and entering alphanumeric responses.

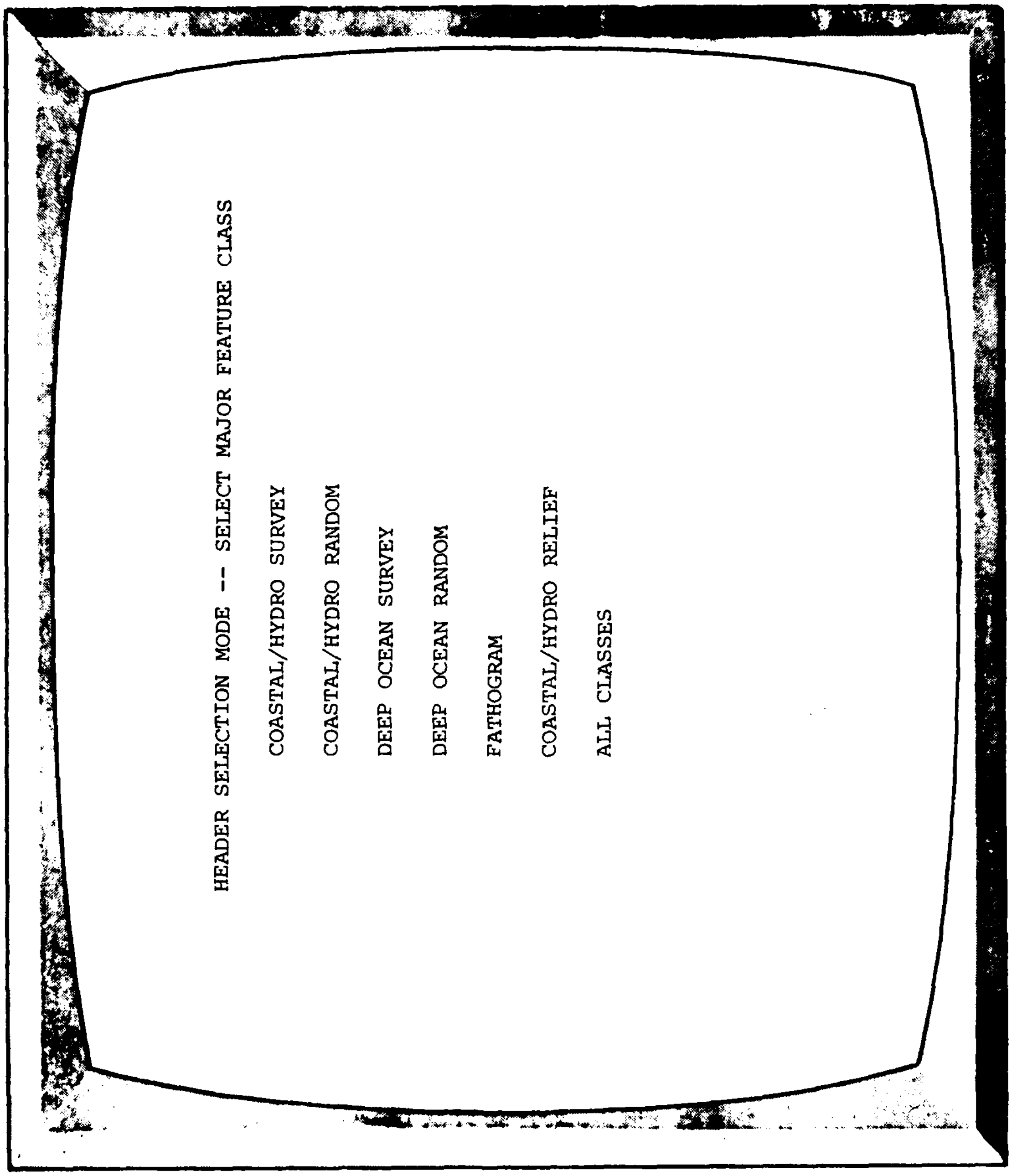

Figure 2-16. Feature Class

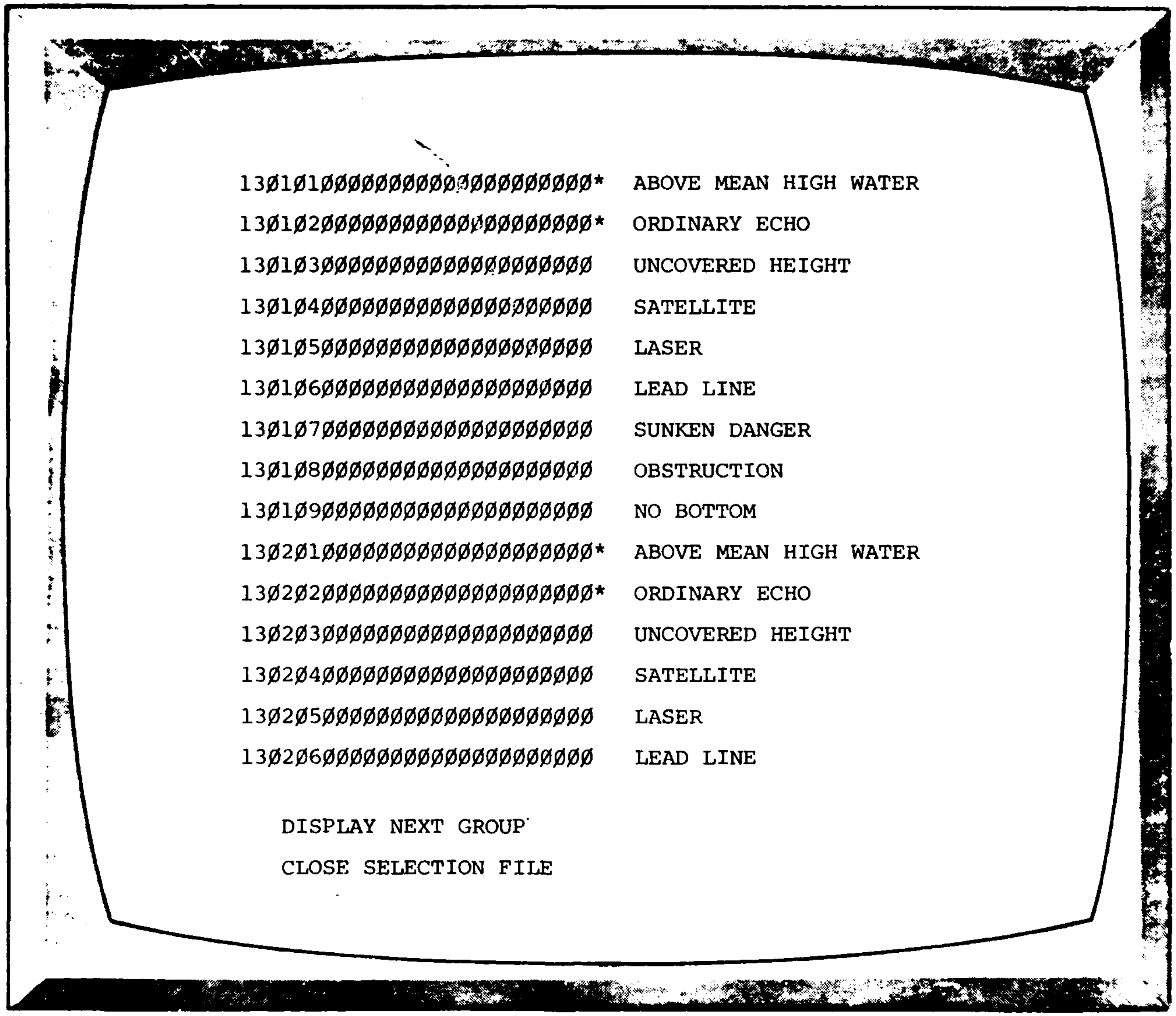

Figure 2-17. Sample Header Group

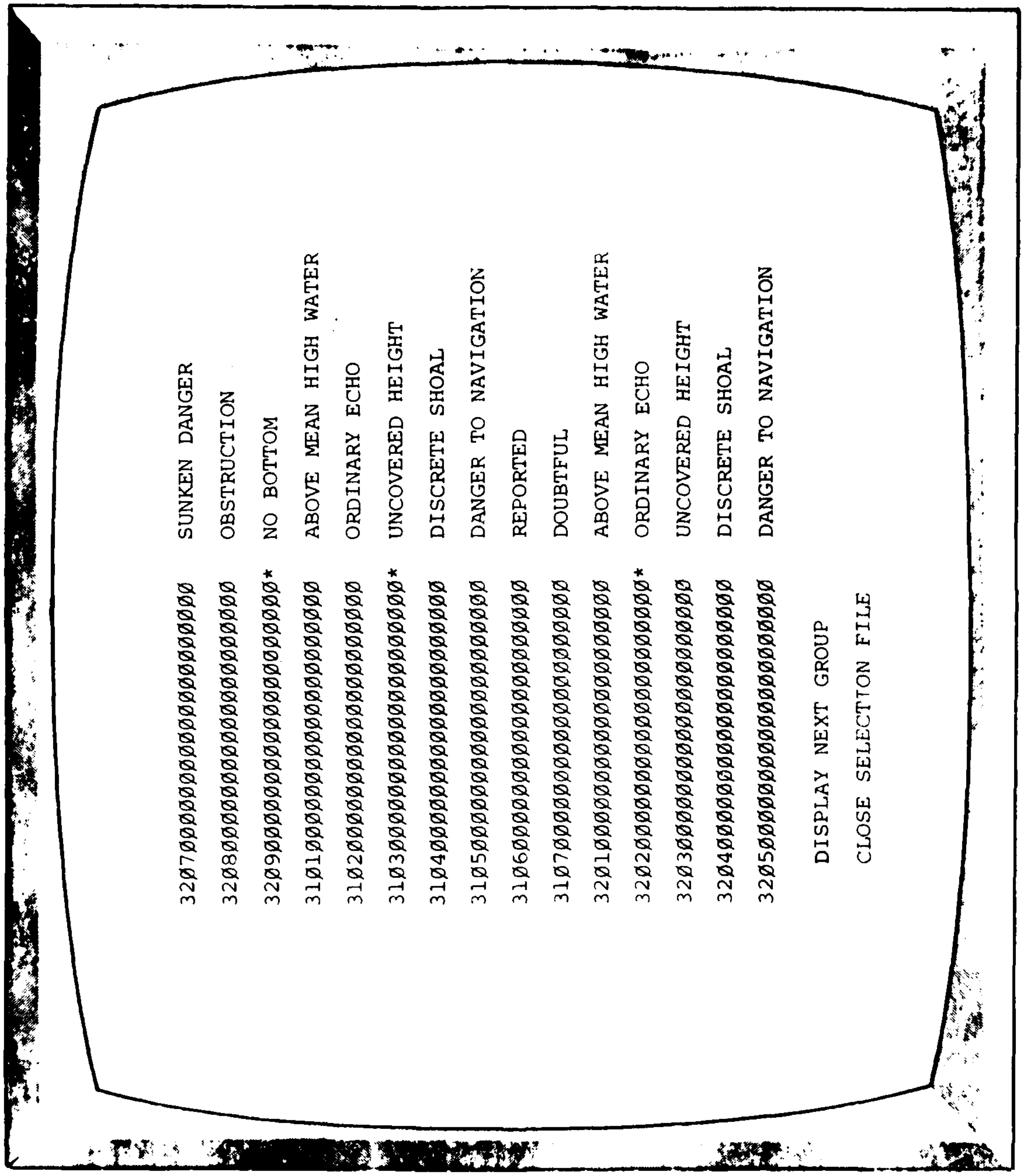

Figure 2-18. Asterisk Indication of Header Selection

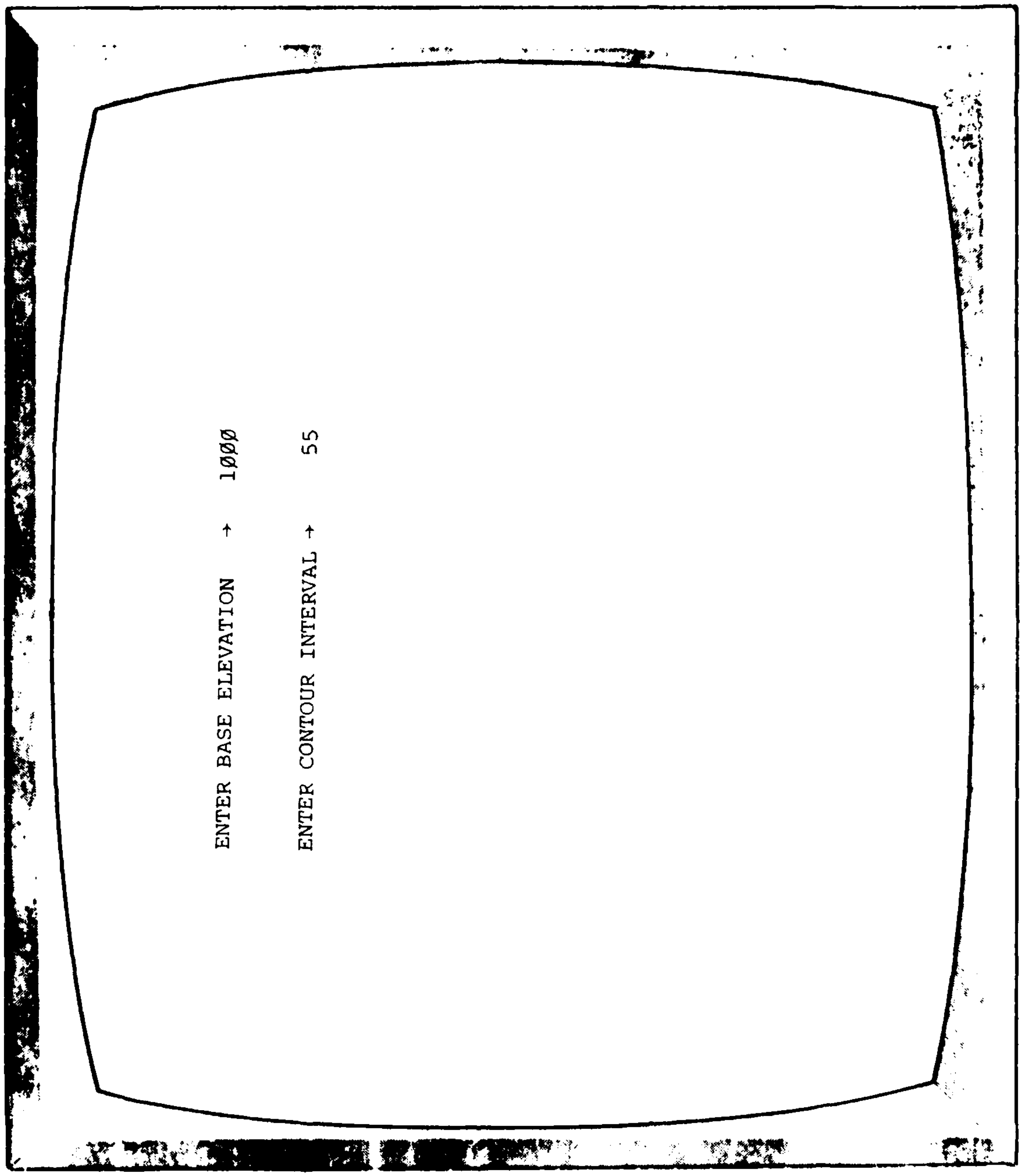

Figure 2-19. Elevation Data Menu

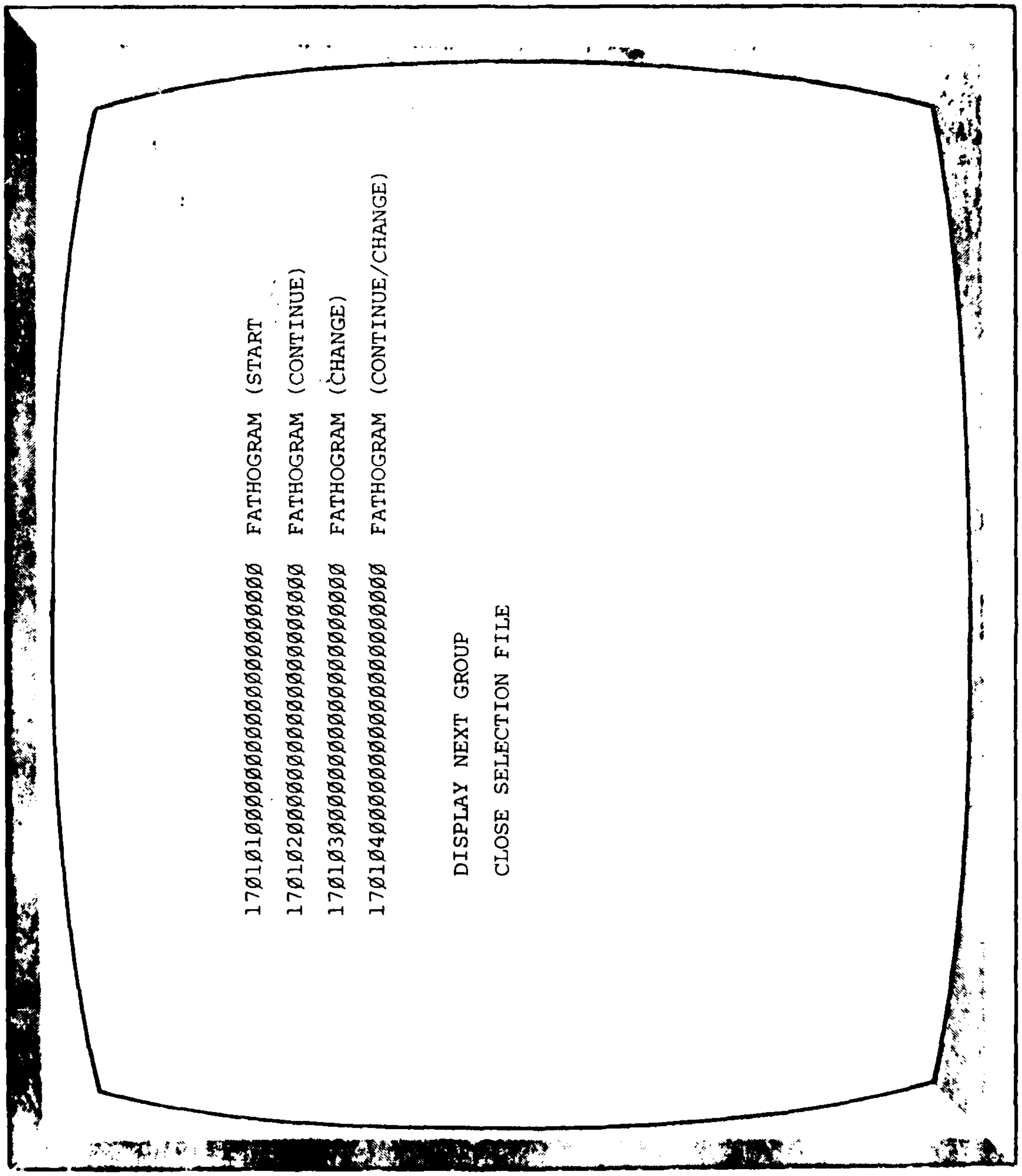

Figure 2-20. Fathogram Data Menu

The operator selects, in hierarchical fashion, the feature class followed by the sub-class and attributes associated with that class and sub-class. The operator may also enter attributes extracted from the DMA Standard Cartographic Feature Digital Identification Data File Master Attribute List. The first menu to be displayed is the DMA Standard Cartographic Feature Category List (Figure 2-21). On selection of the feature category the sub-class/descriptor menu(s) (Figures 2-22 and 2-23) are displayed and the operator continues to enter alphanumeric responses to select the appropriate classification, proceed to the next page (menu), or return to the major category menu. In similar fashion, feature modifiers/attributes are assigned to the feature header following prompts from attribute selection menus (Figures 2-24 and 2-25). Additionally, menus depicted in Figures 2-24 and 2-25 allow the operator to return the major category menu, indicate completion of header, delete the last attribute selected, review a previous page of attributes, advance to the next page of attributes, select the master attribute list, or exit from the header build function. Exiting to the Executive mode (Figure 2-26) permits selection of the working header number (Figure 2-27) and subsequently the digitizing mode required to perform feature digitization.

2.1.7.3 LIS. Each feature within a LIS file has an associated 256-word record of codified and textual information (the feature header record), which is built immediately prior to the generation of topographic data (trailer records). Each time the feature is referenced within the LIS, the operator is presented with the current header record and is given the opportunity to modify its data. Feature headers are composed of codified descriptors and textual data. The operator is requested to supply these data via selection and data entry menus. The first menu presented to the operator by the header build module is the feature class menu (Figure 2-28), which requests that the operator select the class of the feature about to be digitized. The user simply enters the number corresponding to the desired entry and depresses 'CR'. The class selection menu is the top menu of a tree structure. Each class selection begins a path down the tree through type, subtype, and descriptor selection menus. Every class must be broken down into types, but it may or may not be further divided into subtypes. If there is no subtype menu for a chosen class, the type selection menu will be followed directly by the appropriate descriptor selection menu. Figures 2-29 and 2-30 illustrate type and descriptor selection for "ROADS" from the feature class selection menu of Figure 2-28. Descriptor menus are unique in that they may require the selection of more than one item. These menus also allow the user to change the selection at any time before the menu selection is terminated. This can be accomplished in two ways:

a. any selection beneath a heading can be changed to another selection beneath that same heading simply by making a new selection; and

b. a selection can be deleted by reselecting the same menu item.

```
*** HEADER BUILD ***

DMA STANDARD CARTOGRAPHIC FEATURE CATEGORY

0 - CULTURE (FACILITIES AND POPULATED PLACES)
1 - CULTURE (TRANSPORTATION)
2 - CULTURE (DELIMITORS)
3 - COASTAL HYDROGRAPHY/MARINE DANGERS
4 - INLAND HYDROGRAPHY
5 - HYPSOGRAPHY (AND RELATED LAND FORMS)
6 - MARITIME FEATURES AND NAVIGATION AIDS
7 - VEGETATION
8 - AERONAUTICAL FEATURES AND NAVIGATION AIDS
9 - RELATED AERO/MARITIME FEATURES AND NAVIGATION AIDS

ENTER CATEGORY NUMBER [CR]

ENTER "E" TO EXIT

ENTER NUMBER → 3
```

(Assume category 3 selected
Go To Figure 26)

Figure 2-21. Major Category Menu

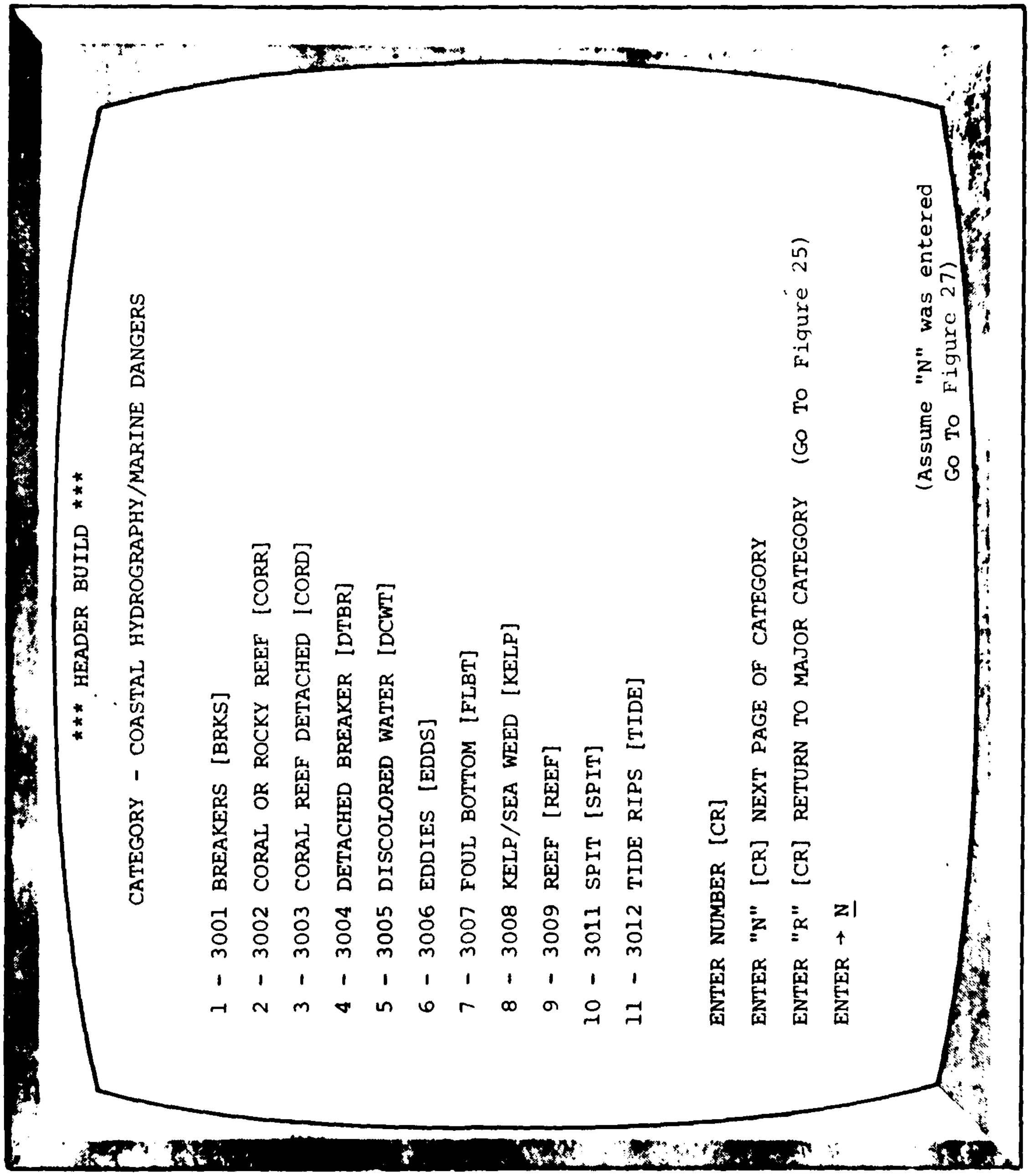

Figure 2-22. Sample Sub-Class/Descriptor Selection Menu (1)

```
*** HEADER BUILD ***

CATEGORY - COASTAL HYDROGRAPHY/MARINE DANGER

1 - 3015 ANCHORAGE PROHIBITED AREA [ANCP]
2 - 3016 DISPOSAL AREA [DISA]
3 - 3017 DOLPHINS [DOLP]
4 - 3018 DUMPING GROUND [DMPG]
5 - 3019 FOUL GROUND [FOLG]
6 - 3020 OBSTRUCTION [OBST]
7 - 3021 OYSTER BED [OYST]
8 - 3022 PERCHES [PERC]
9 - 3023 PILES, PILING [PILE]
10 - 3024 PROHIBITED AREA [PROH]
11 - 3025 QUARANTINE ANCHORAGE AREA [QUAR]

ENTER NUMBER [CR]
ENTER "N" [CR] NEXT PAGE OF CATEGORY
ENTER "R" [CR] RETURN TO MAJOR CATEGORY
ENTER → 1_
```

(Go To Figure 28)

Figure 2-23. Sample Sub-Class/Descriptor Selection Menu (2)

```
                        *** HEADER BUILD ***
          CATEGORY - COASTAL HYDROGRAPHY/MARINE DANGER

 CAT   ATB1  ATB2  ATB3  ATB4  ATB5  ATB6  ATB7  ATB8  ATB9   ATB10 ATB11  ATB12
 3015  001   ---   ---   ---   ---   ---   ---   ---   ---    ---   ---    ---
 ANCP  BANK  ----  ----  ----  ----  ----  ----  ----  -----  ----- -----  -----

1 - 001 BANK [BANK]                              9 - 009 OVERFALLS [OVFL]
2 - 002 CORAL [CORL]                            10 - 010 RIDGE [RIDG]
3 - 003 ISOLATED DANGER [ISDG]                  11 - 011 SEAWEED [SEAW]
4 - 004 KELP [KELP]                             12 - 012 SHOAL [SHOL]
5 - 005 LEDGE [LEDG]                            13 - 013 STANDING HARBOR [STHA]
6 - 006 LESSER DEPTHS POSSIBLE [LDPS]           14 - 014 TIDE LIMIT [TILI]
7 - 007 OBSTRUCTION [OBST]                      15 - 015 UNKNOWN EXTENT [UNEX]
8 - 008 OF UNKNOWN EXTENT [UNEX]                16 - 016 AWASH [AWSH]

                      ENTER ATTRIBUTE NUMBER [CR]
ENTER "R" [CR] RETURN TO CATEGORY           ENTER "N" [CR] NEXT PAGE OF ATTRIBUTES
ENTER "F" [CR] FINISHED WITH HEADER         ENTER "M" [CR] FOR MASTER ATTRIBUTES
ENTER "D" [CR] DELETE LAST ATB              ENTER "E" [CR] TO EXIT
ENTER "P" [CR] PREVIOUS PAGE OF ATTRIBUTES
                          ENTER → 1, 12, N
                                                (Go To Figure 29)
```

Figure 2-24. Sample Attribute Selection Menu (1)

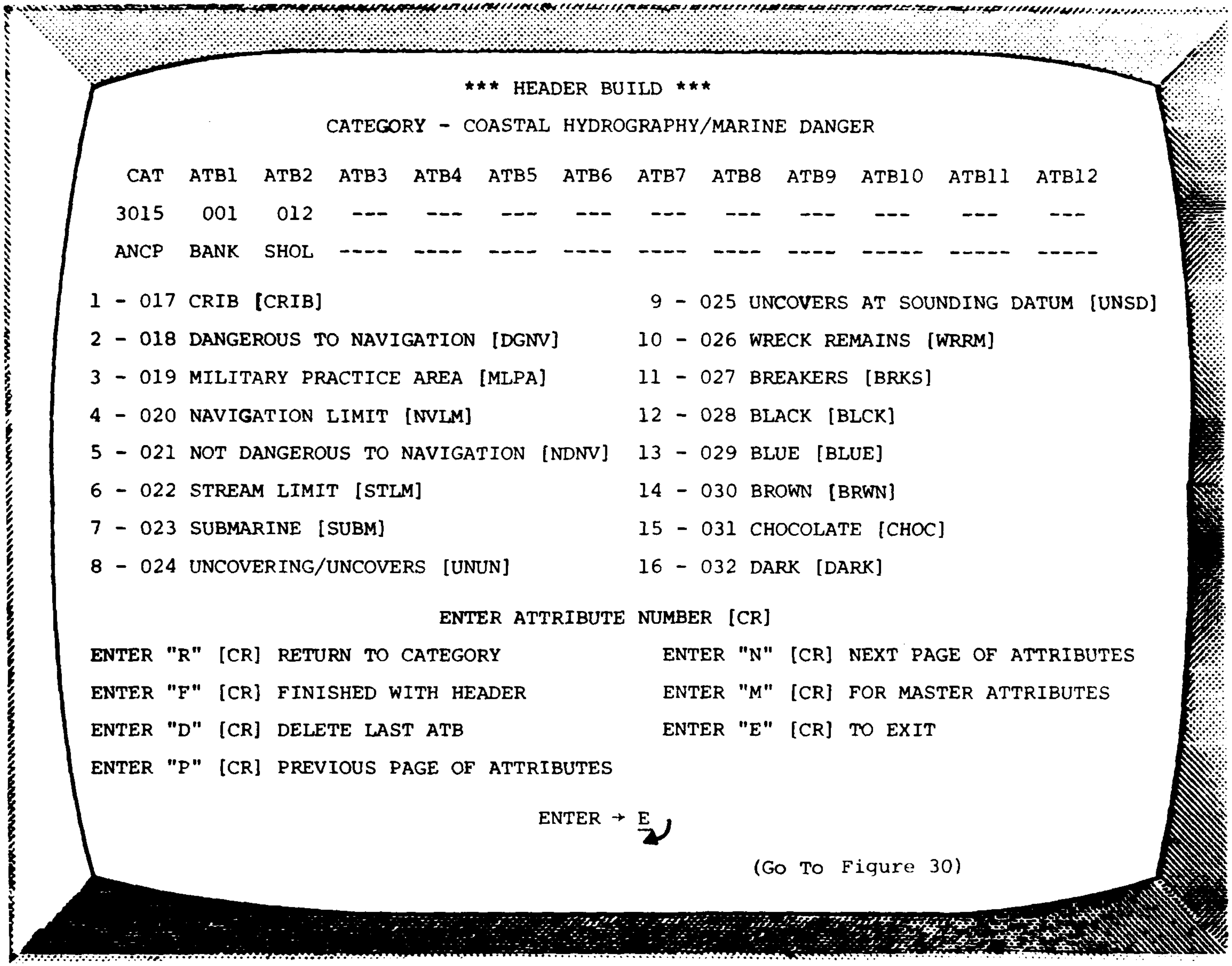

Figure 2-25. Sample Attribute Selection Menu (2)

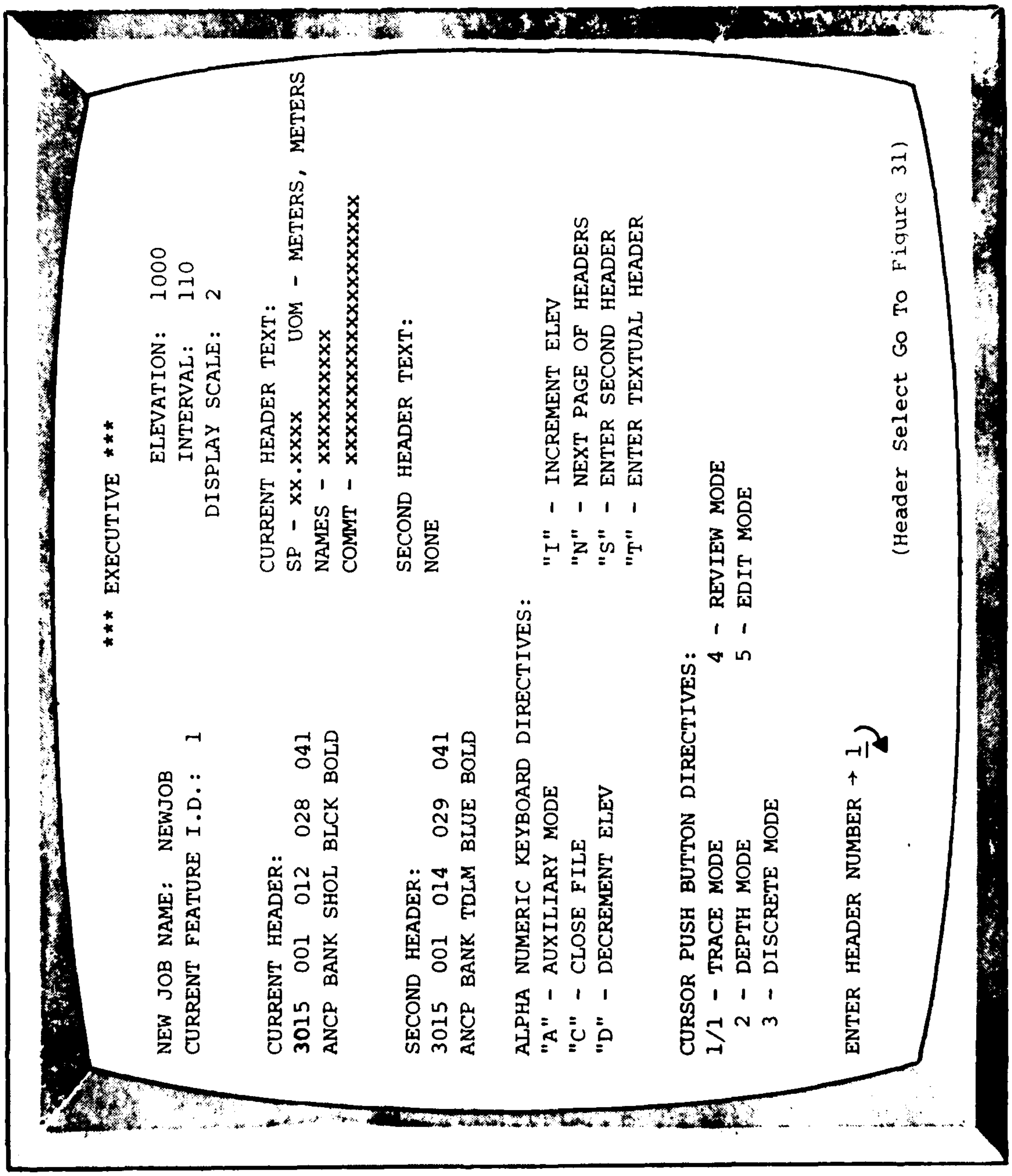

Figure 2-26. Executive Menu

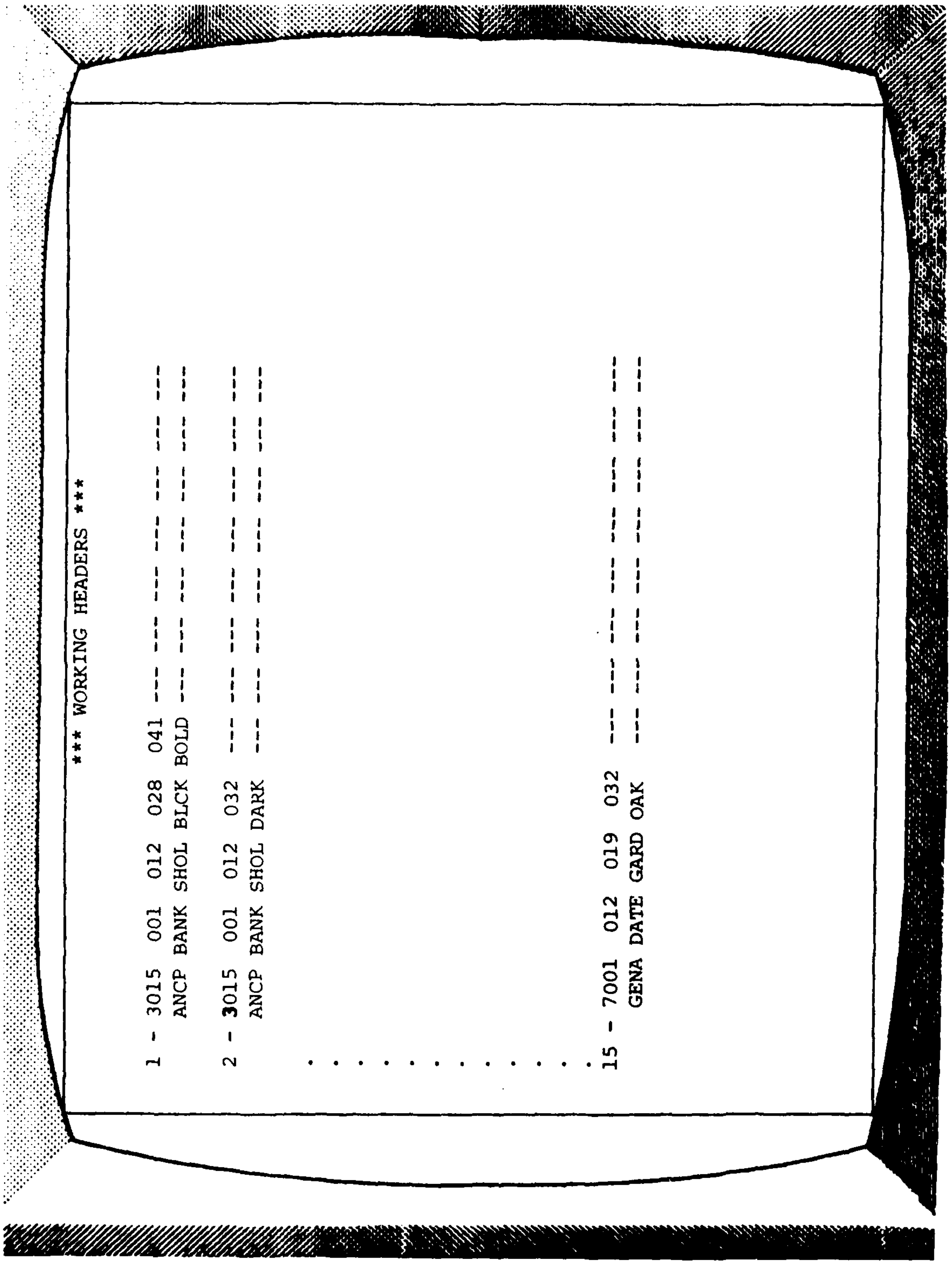

Figure 2-27. Working Header List Menu

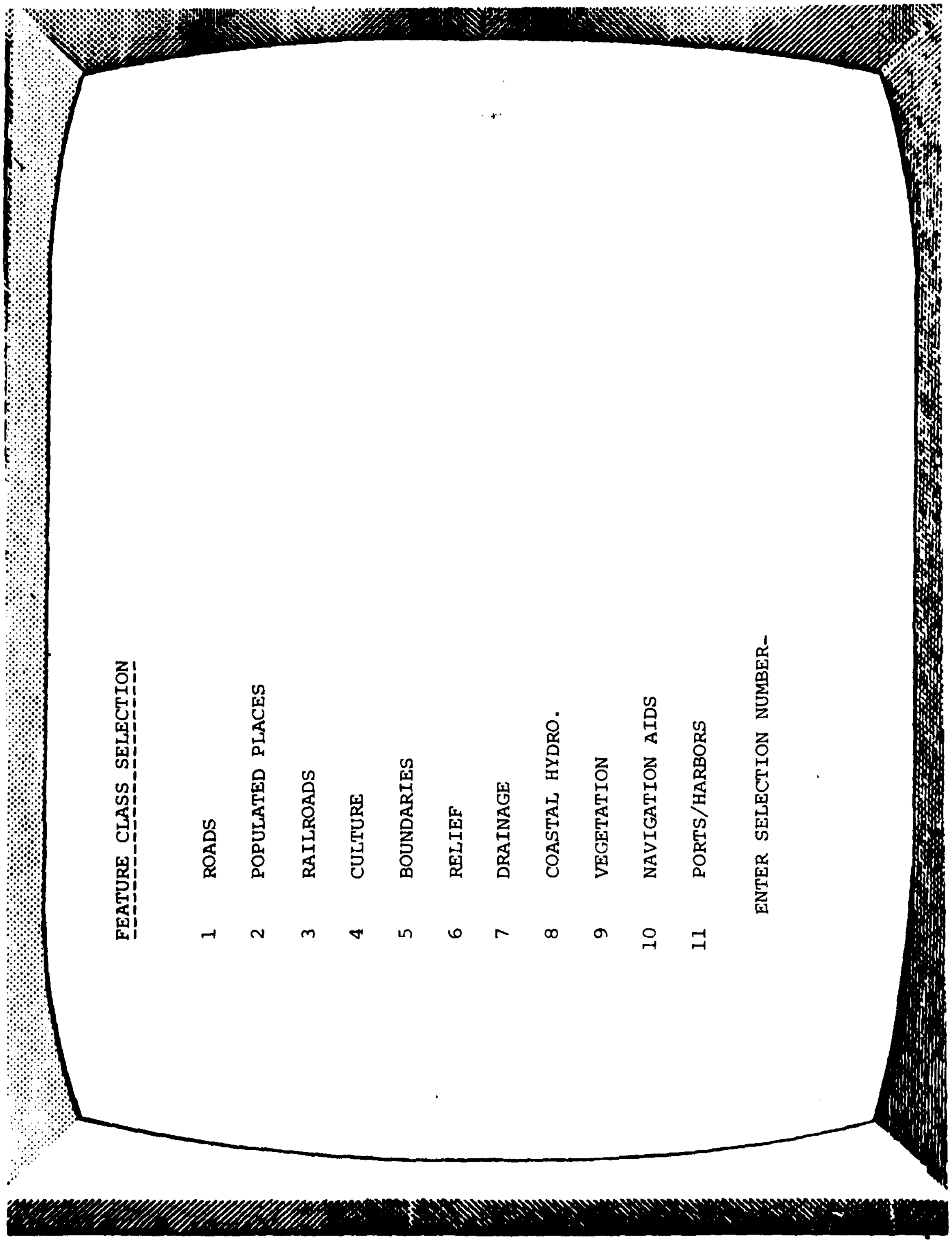

Figure 2-28. Feature Class Selection Menu

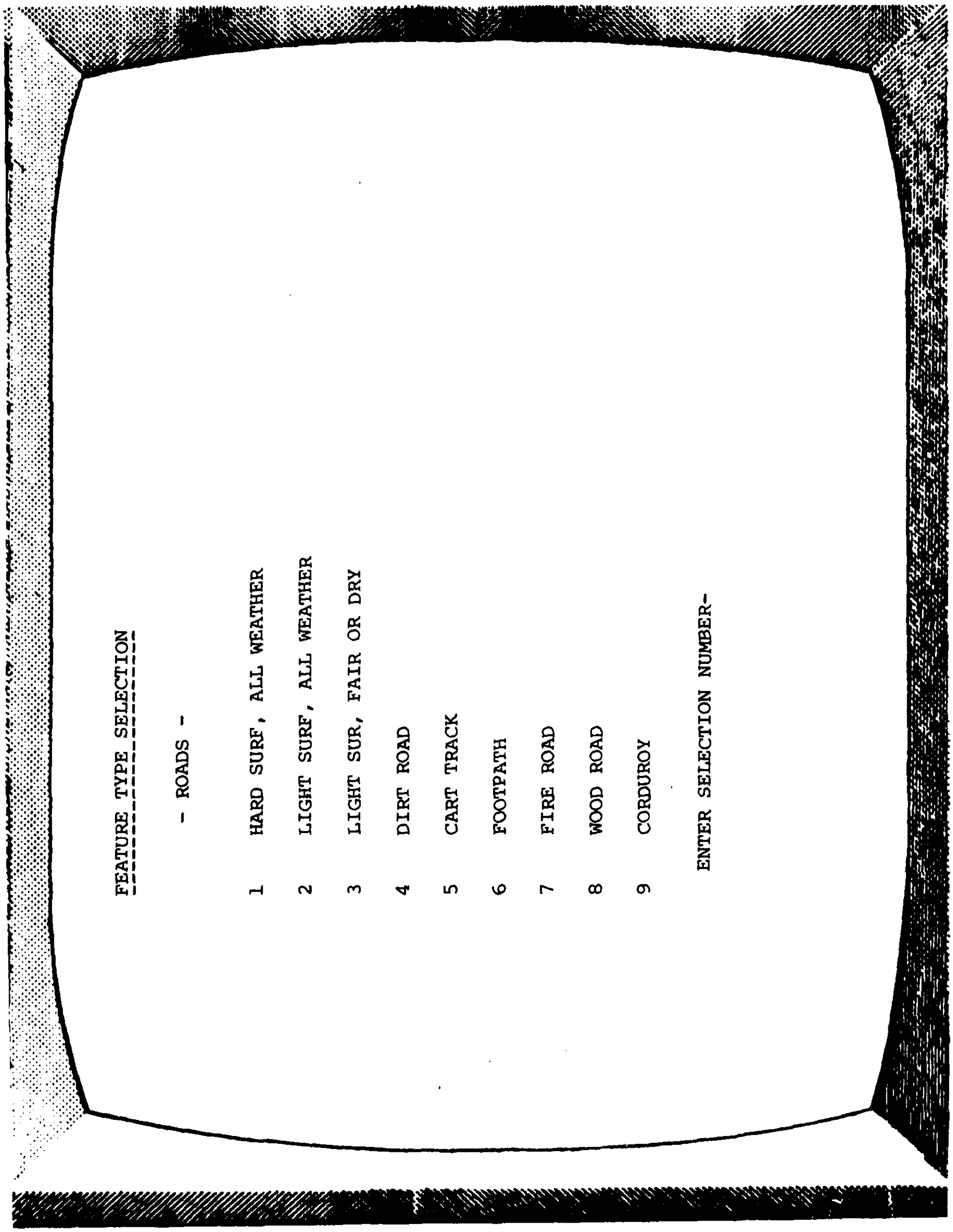

Figure 2-29. Feature Type Selection Menu

```
DESCRIPTOR SELECTION
        - ROADS -
ALIGNMENT
2     ACCURATE
3     APPROXIMATE
4     DOUBTFUL
USABILITY
6     PUBLIC
7     PRIVATE
8     PROPOSED
9     UNDER CONSTRUCTION
10    UNDER REPAIR
11    ABANDONED
WIDTH
13    ONE LANE
14    TWO LANES
15    THREE LANES
16    FOUR LANES
17    MORE THAN FOUR LANES
18    DIVIDED TWO LANE
19    DIVIDED FOUR LANE
20    CONTINUE DESCRIPTOR SELECTION
          ENTER SELECTION NUMBER-
```

Figure 2-30. Descriptor Selection Menu

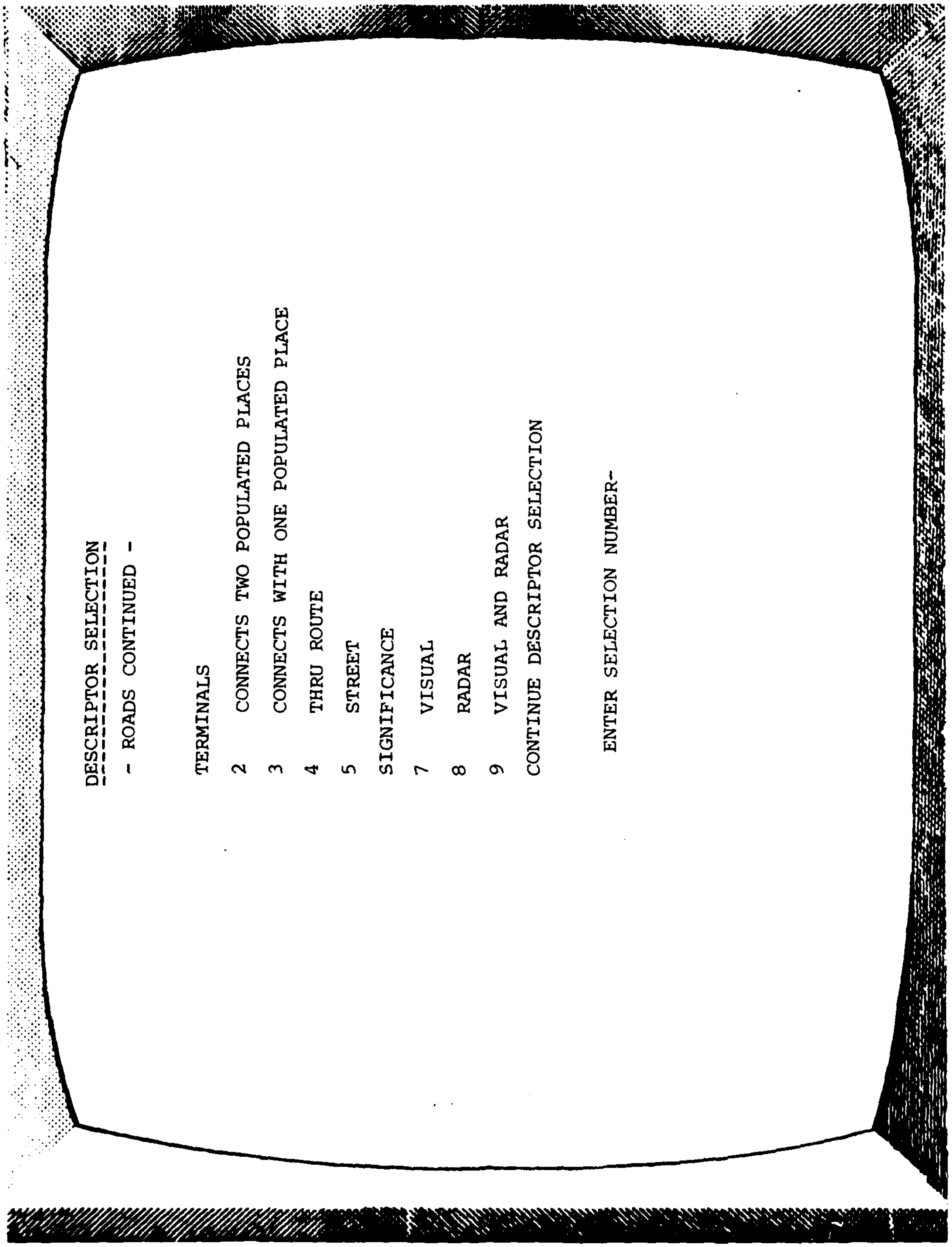

Figure 2-30. Descriptor Selection Menu (Continued)

During the header build procedure, a data entry descriptor menu may also be presented. These menus are handled in the normal manner. The last descriptor selection for a header is the "HEADER COMPLETE" selection. When this selection is made, the new header is presented to the user for acceptance or editing.

Immediately after a header has been built, the feature header is displayed in summary form for the user's approval. Figure 2-31 illustrates a sample header record summary display composed from the menus in Figures 2-28 through 2-30. It should be noted that to ensure clarity, the first eight characters (only) of the descriptor headings are displayed preceeding the descriptor text and that in this example no "subtype" entry is possible. Immediately to the left of each header item appears a line number which is used to select a particular field for editing purposes. Also note that the presence or absence of Radar Data is now shown in the Header Summary. To determine which Radar Data entries have been made, it will be necessary for the user to select item 15 for "editing".

2.2 SCANNING CURSOR PROGRAMS

This subsection reviews the procedures and methodology relative to the scanning cursor programs currently being utilized. The following paragraphs pertain to the LIS Digitizing Workstation Interface Description, Aided-Trace Digitizing System Interface, Tracking Error Correction, Computer Flow Diagram, and Measured Performance Characteristics for Aided-Track Digitizing.

2.2.1 Introduction

Manual tracing operations on digitizing tables are currently used in converting cartographic feature coordinates to digital values for storage and subsequent processing. This procedure consists of maintaining a hand-held cursor cross-hair centered over the feature being digitized. Cursor position is sensed by such techniques as servoed-slaved carriages linked to optical encoders or coded grids embedded in the table surface using electro-magnetic or magneto-strictive ranging. The inherent machine accuracies cannot be conistently met because the tracing process becomes quite tedious. Consequently, this operation is time consuming and produces errors that necessitate costly digital editing efforts.

The development of an aided-track scanning cursor was intended to ease the manual digitizing of graphic material by removing the restriction of maintaining high conversion accuracies by exact positioning of the cursor cross-hair on the traced feature. It permits tracing deviations

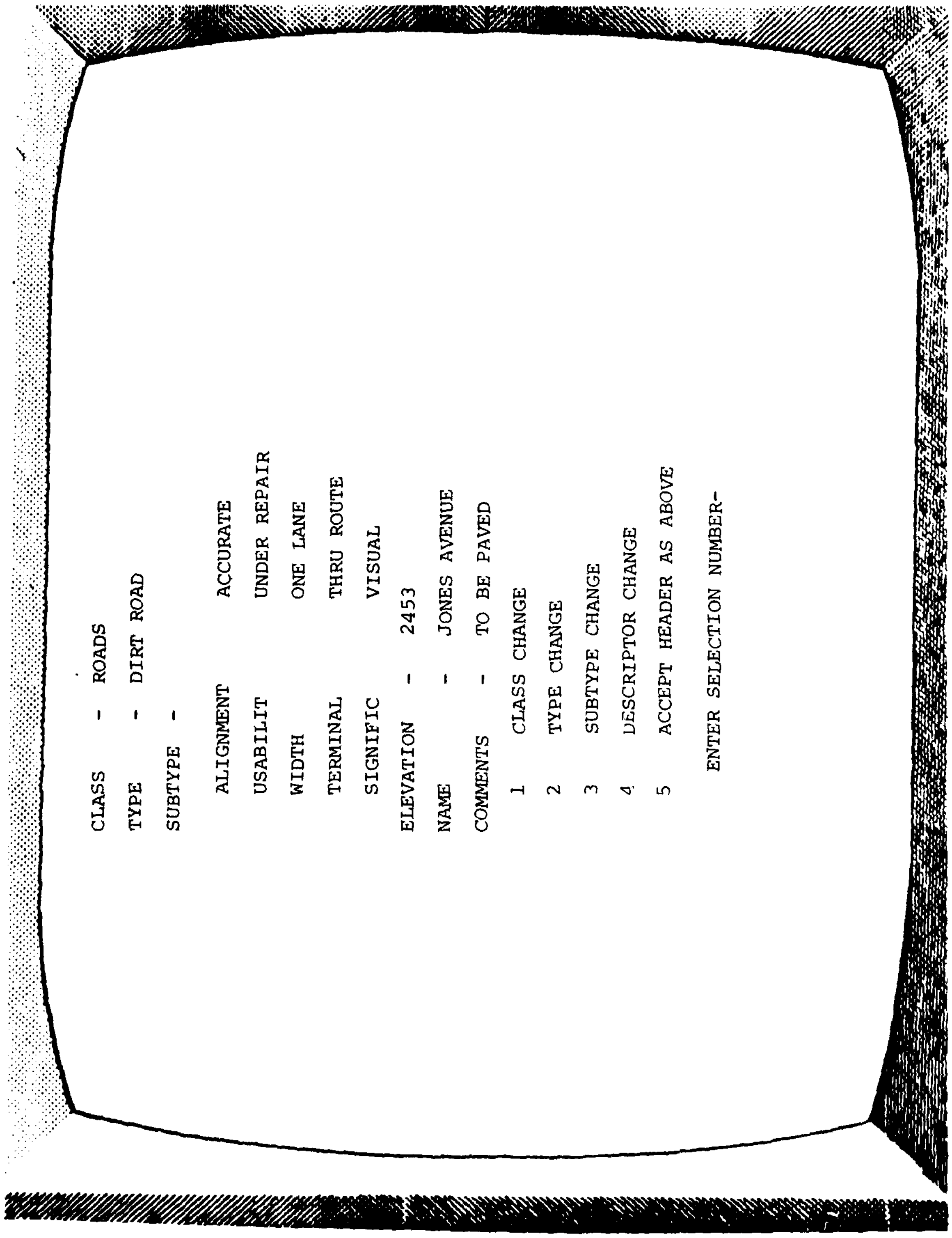

Figure 2-31. Sample Header Display

of ± 30 mils(0.762mm) from the cross-hair center, automatically providing correction terms to accommodate these offsets in the table coordinate values transferred to the workstation computer. The system is capable of correcting closed-contour features and of operation with both back-lighted translucent graphic materials and opaque manuscripts.

Figure 2-32 illustrates the components of the scanning cursor system. It is composed of three units (computer, video processor, and cursor) which electrically interface by simple cabling interchanges with the digitizing workstation. The aided-track cursor shown incorporates a photosensitive device to sense small position variations of the map feature relative to its initial position as it is traced. These variations are then used to generate corrections to the table encoded cursor coordinate values. By allowing the operator to make small errors which are automatically computer-corrected, the overall process is improved in its digitizing accuracy; consequently operator efficiency and output are increased.

The video processor unit contains the required analog/digital signal processing circuitry for converting a detected feature location along the array to a count value. This count is then transferred to the intermediate computer where correction terms are derived and applied to the table encoder values. In addition, the video processor contains the array scan controls and the servo drive circuitry.

The intermediate minicomputer interfaces with the digitizing table and the aided-track cursor. Correction algorithms use the inputs from these sources to produce corrected coordinate values in the presence of tracing inaccuracies. In addition, computations are performed to generate a command signal to maintain the array angle perpendicular to feature curvatures to preserve correction accuracy. Figure 2-33 is a functional block diagram showing the system interface with typical work stations to be found at production-oriented cartographic facilities.

The capability of the aided-track system to provide accurate digitized data bases has been demonstrated and evaluated by previous RADC efforts. These efforts document the significant improvement in digitizing accuracy as indicated by the measured RMS errors of 1.47 mils (0.04mm.) versus 2.54 mils (0.07mm.) of the corrected and manual traces, respectively. This improvement was accompanied by a 3:1 increase in tracing speed.

2.2.2 LIS Digitizing Work Station Interface Description

The aided-track computer program described in this document was developed for use with the Lineal Input System (LIS) presently installed at Defense Mapping Agency (DMA) centers. A Hewlett-Packard 21 MX-series

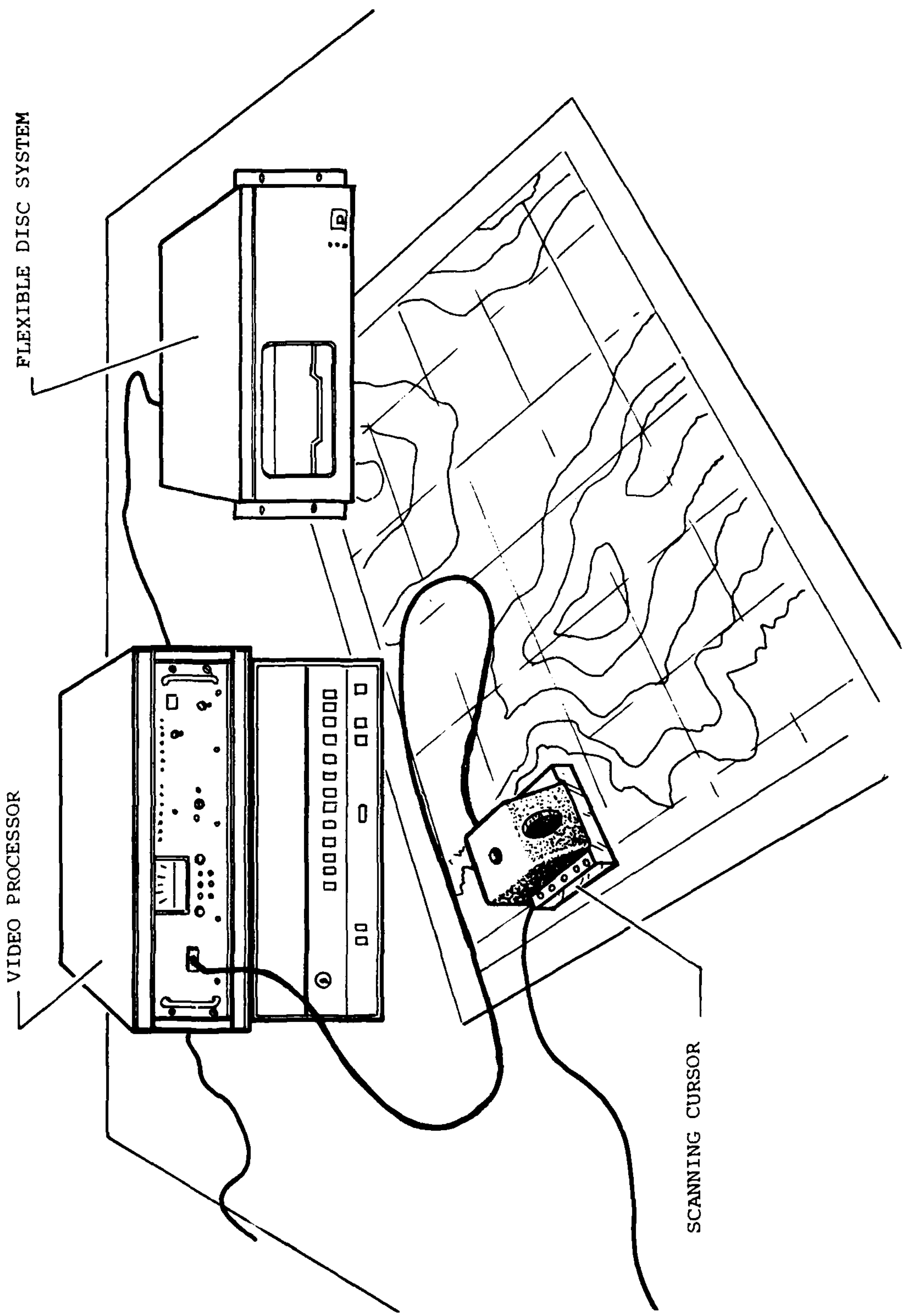

Figure 2-32. Scanning Cursor System

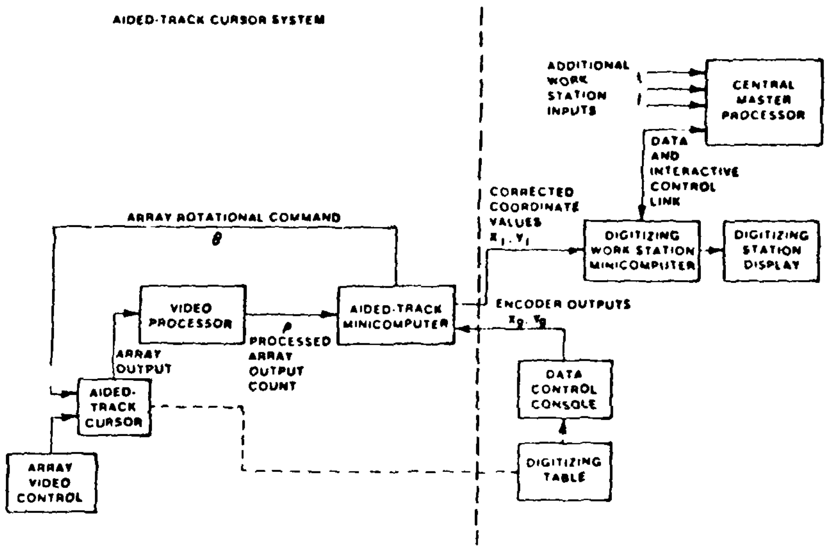

Figure 2-33. Block Diagram Showing the Aided-Track Cursor System Interface with a Typical Digitizing Work Station

minicomputer was used in interfacing the station Gradicon[1] digitizing table and IMLAC PDS-ID computer to the aided-track scanning cursor system.

Coordinate data is generated in the Gradicon[1] digitizer by means of incremental optical encoders coupled to an x-y guide system. This guide drives a carriage which is slaved to the cursor by a servo system using electro-magnetic position sensing. Located just below the transparent glass top of the digitizing table, the carriage contains sensing coils to derive the necessary servo signals and carries a controllable DC light source for localized backlighting of manuscripts.

The aided-track system improves the efficiency of the manual digitizing operation by providing a circle as the cursor tracing reticle, replacing the crosshair normally used. In tracing features, correction terms are automatically generated by means of a linear, self-scanning photosensitive array within the cursor. Displacements of the traced feature from the encoder fiducial mark are derived in terms of counts to the position of the feature detected by the array and are used to provide correction counts to the table encoder outputs. Feature curvature is accommodated by maintaining the array orthogonal to the feature during the trace. The details of the scanning cursor system are documented in literature and reports listed in Appendix B.

2.2.2.1 Data format. Each coordinate point encoded by the Gradicon[1] digitizer is defined by a three word data transfer consisting of the status word, x-coordinate value, and y-coordinate value. Each word is 16-bits in length and is transferred bit-parallel in the above sequence. The status word indicates table error conditions, point or incremental operating mode, x-y sign, and closures of the cursor control switches. A maximum coordinate count value of 65,535 is possible from the table output registers. The three words are multiplexed onto a common data bus for transfer to the Imlac computer.

2.2.2.2 Interface control signals. The data transfer sequence is initiated by a Gradicon flag occurring at fixed spatial distances. The basic table resolution is 10-microns (0.394 mils). A selector switch on the Gradicon data console permits selection of a multiple of this basic resolution to 90-microns (3.5 mils).

In addition to choice of resolution, a data console selector switch is available to reduce the number of data points transferred by skipping a pre-selected number of resolution counts before outputting a new point. The DMA hydrographic office has standardized the digitizer parameters to a resolution of 20 microns, (0.79 mils) with data outputted for increments of 40 microns in x or y position: this is a condition for data transfer. Under this condition, an average of 10-20 points per

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1/ Gradicon is the trade-name of Instronics Limited, Ottawa, Canada.

second (x and y) are transferred in precision tracing operations.

The Gradicon flag received by the Imlac starts an automatic data transfer operation in which the Imlac sequentially generates transfer status word, transfer x-word, transfer y-word pulses on three separate control lines. After generating the transfer y pulse, the appropriate counter circuitry in the Gradicon data console is enabled to continue count accumulation. The control line used in resetting the Gradicon circuitry is not available on the connector used to interface the Scanning Cursor System to the Gradicon - Imlac configuration used in a typical LIS digitizing work station.

2.2.2.3 Timing and transfer rates. The Gradicon table manufacturer's specification states a maximum digitizing speed in the order of 12-inches per second (304.8mm.) at the highest resolution before an error occurs due to data "over-run." This translates to a maximum conversion rate of 30,500 coordinate points per second. Practically, the tracing rate is limited to a drastically lower number (by orders of magnitude) by virtue of the manual function required by the operator. The digitizing rates are, effectively, operator rather than machine limited. At higher rates the data can be grossly in error depending on the tightness of the servo loop in controlling the position of the encoder gantry to follow the cursor motions.

2.2.3 Aided-Trace Digitizing System Interface

The addition of an aided-trace system to increase digitizing efficiency must observe and accommodate existing operating parameters and interface controls of the LIS equipment. The Hewlett-Packard Series 2108 computer of the Scanning Cursor System has an I/O configuration making it transparent to the work station equipment, i.e., the Gradicon-Imlac interface is both mechanically and electrically duplicated by the computer. A block diagram of the overall aided-track system is shown in Figure 2-34. Physically, the addition of the aided-track equipment is accomplished by a single reconnection of the data and control lines running between the Gradicon and Imlac units, and substitution of the station cursor with the aided-track scanning cursor.

The HP 12566B interface used in the present configuration is for general purpose applications. These devices provide dual 16-bit registers for bi-directional data transfer between the HP computer and peripheral equipment (Gradicon and Imlac units). A Device Command signal from the interface card enables the peripheral device and, optionally, gates the the output register to the output lines. The card accepts a Device Flag signal from the peripheral device to gate data into the input register and to generate an interrupt signal to the computer. Control signal

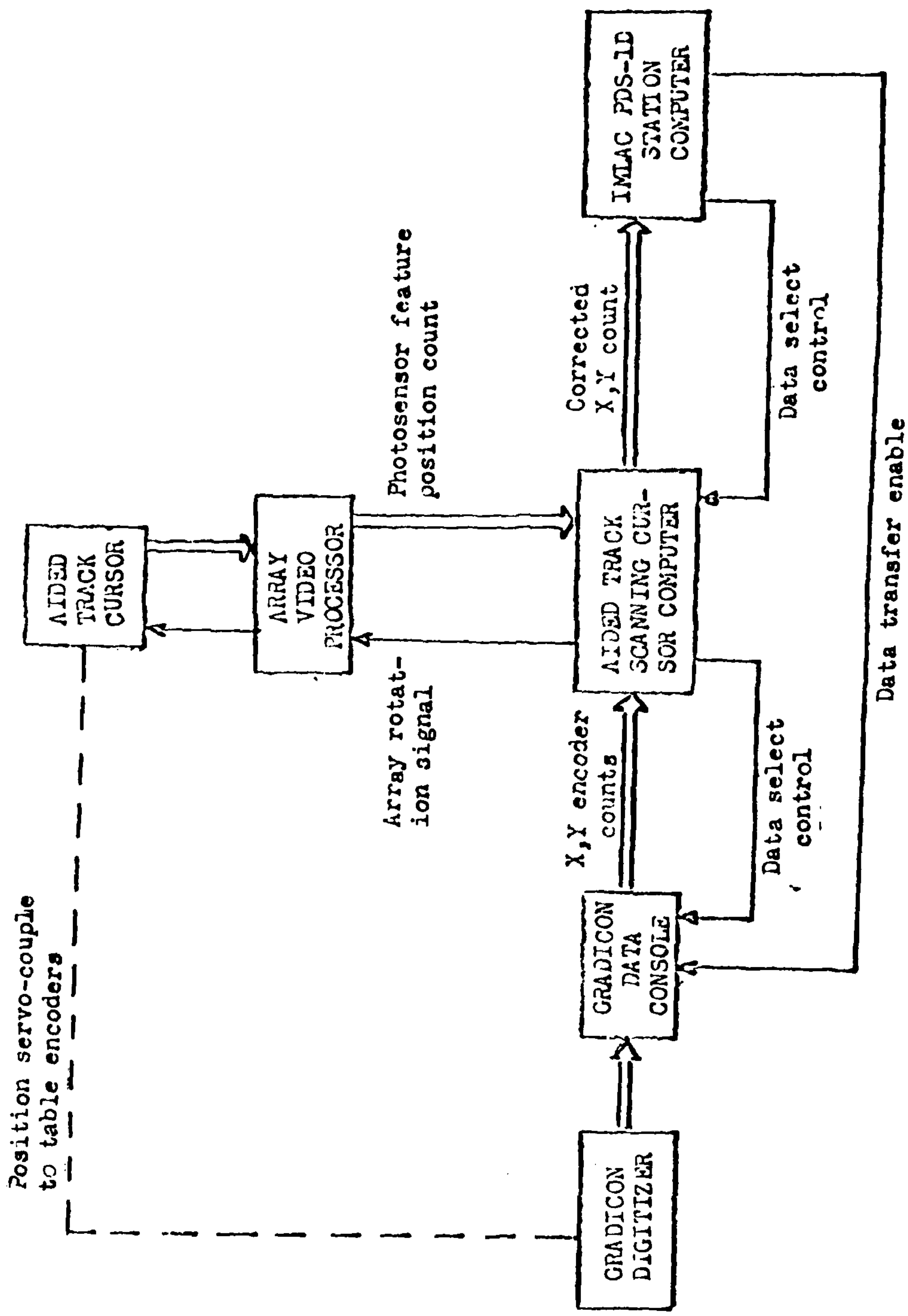

Figure 2-34. Aided-Track Digitizer Block Diagram

and data lines are compatible with TTL logic levels and speed. Input and output data are negative-true logic. In its application in this system, the interface board is configured by appropriate jumpers to provide a pulsed Device Command signal for strobing functions, as described in the interface discussion. The interface concept used (shown in Figure 2-35) is a customized one, requiring external control hardware designed to multiplex signals onto the data bus.

At the end of each execution cycle of the HP program, bit 4 (B4) is set high and transferred to the output side of Control FF4 using the Device Control FF of I/O board 11 (HP I/O 11) to strobe the data. FF4-Q enables AND gate A. Data transfers are initiated by a FLG from the Gradicon data console. The Gradicon flag is transferred through OR or gate B to set the HP flag of I/O 12. In normal operation, the cursor program sits in a wait loop at I/O 12 checking its flag. When the flag is set, the program produces consecutive pulses at the outputs of FF1, 2, and 3 simulating the Imlac status word select, x select, and y select data strobes (respectively). As each Gradicon word (parallel 16-bit length) is entered onto the HP data bus in sequence, the word is stored in memory. The program will then proceed to check the flag of I/O 11, enabling the video processor flag gate C by means of Control FF5. When set via OR gate D, the parallel 8-bit video processor word is transferred onto the HP I/O bus and stored in memory. (The video processor word consists of 6-bits corresponding to the array output count, B0-B5, and 2 status bits, B6 and B7.) The program then calculates the desired correction terms and modifies the Gradicon input x and y words. Corrected x and y words as well as the status word are loaded into I/O 10, 12, and 11, respectively.

The Device Control FF of I/O 10 is used to signal the Imlac to initiate the data transfer. A select status word, select x, and select y sequentially sets the flags of each I/O in turn. On transfer of the y data, the Imlac will enable the status and data transfer registers of the Gradicon on a remote line. The scanning cursor program will then calculate a new orthogonal angle for the array and output the 10-bit angle value to the cursor video processor, using a flag signal generated on the Device Control line of I/O 12. The program execution cycle is ended at this point and the program jumps to the Gradicon flag wait-loop to accept the next set of data coordinate values.

2.2.4 Tracking Error Condition

The following subparagraphs pertain to the derivation, vectoring, and array angle calculation aspects of tracking error correction.

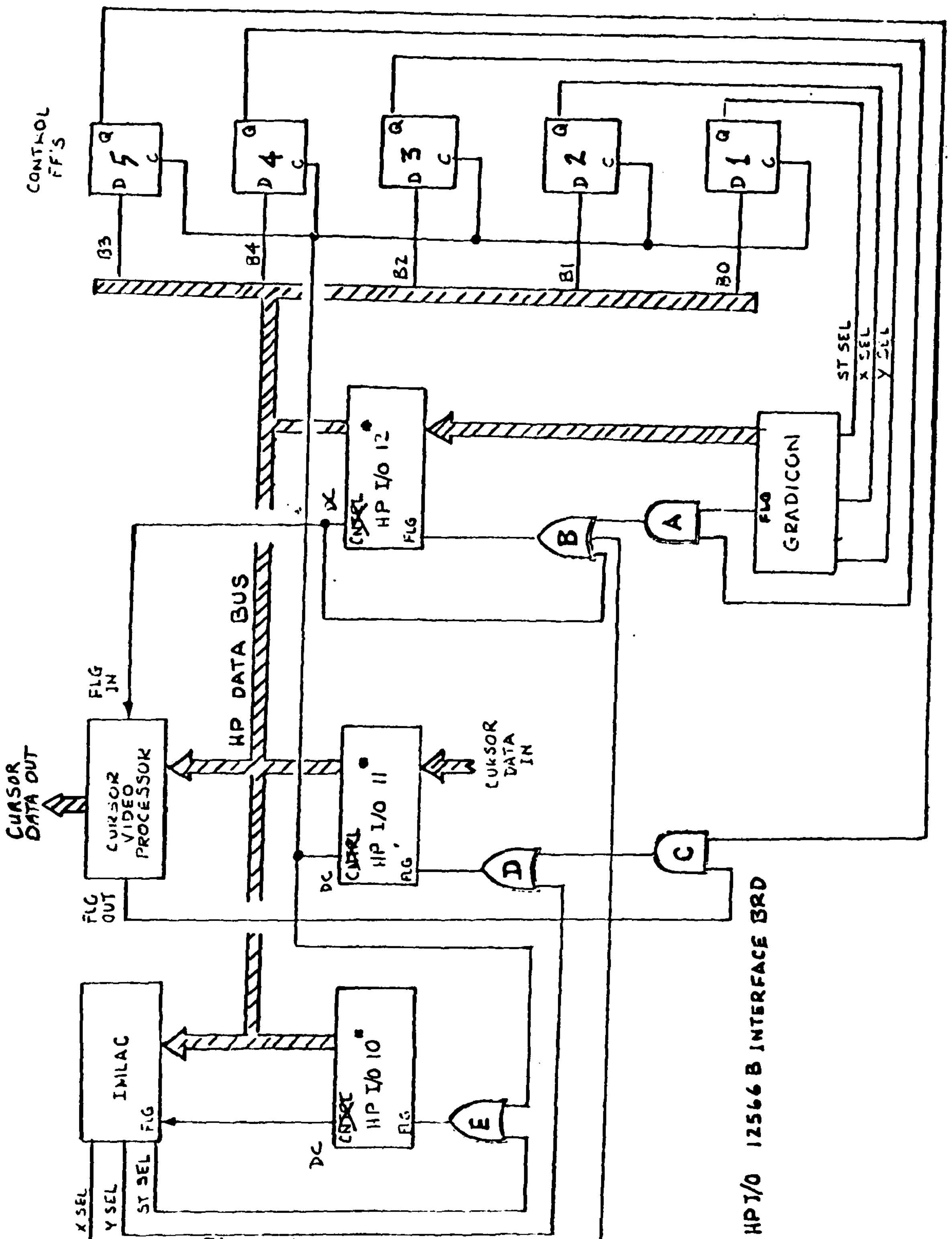

Figure 2-35. LIS Scanning Cursor Interface

2.2.4.1 Derivation. The 64-element linear photodiode array in the RCA scanning cursor determines the location of the center of a feature line within a tracing circle in array counts and passes this count to the HP computer. Counts outside the reticle aided-trace circle are eliminated in the video processor. The array count data, RHO, is transmitted to the computer as bits 0-6 of an 11-bit word. Bits 7 and 8 represent start-of-feature and calibrate mode, respectively.

The correction factors to correct the Gradicon data for tracking errors are calculated in the following formulas:

$$X_c = RC \cos \theta \quad \text{. . . . . equation (1.1)}$$

$$Y_c = -RC \sin \theta \quad \text{. . . . . equation (1.2)}$$

where

$$R = (\rho - A_c) - (X_0 - A_c) \cos \theta + (Y_0 - A_c) \sin \theta$$

$$C = 24.5\ S/W$$

and where

X_c = DELX = X coordinate correction

Y_c = DELY = Y coordinate correction

θ = THETA = angular position of the array from the horizontal

ρ = RHO = array reading, in array counts

A_c = ACN = center of rotation of array, in array counts

X_0 = XCFC = location of center of reticle along x axis, in array counts

Y_0 = YCFC = location of center of reticle along y axis, in array counts

C = CONST = conversion of array counts to Gradicon units

S = SPAC = array spacing, in mils

W = RESOL = Gradicon resolution, in micrometers.

Quantities ACN, XCFC, and YCFC represent alignment off-set counts with respect to the center of the reticle, 0, imaged onto the array plane. These quantities are measureable and constant for a given array and reticle. A calibration procedure determines and stores these values in the computer. The scanning cursor algorithm accounts for the effects of these off-sets, permitting a non-critical alignment procedure during cursor assembly.[1]

The correction factors can be derived as follows (Figure 2-36 represents a line being tracked by the array whose axis is along the line A-Z):

Let B = projection of the center of rotation of the array R_c on the array. This point does not move as the array rotates.

Let F = location of center line of curve being tracked, normal to the array.

Let $\overline{AB} = A_c$ = ACN = center of array rotation, in array counts.

Let $\overline{AF} = \rho$ = RHO = array reading, in array counts.

Let 0 = center of coordinate system which is centered on the axis of the cursor reticle.

Then:

$\overline{CF} = \overline{OF'} = R$ = distance from origin to line

X_0 = XCFC = $(\overline{OD} + \overline{AB})$ = ($\overline{AO}$ when array is parallel to x axis)

Y_0 = YCFC = $(\overline{OE} + \overline{AB})$ = ($\overline{AO}$ when array is parallel to y axis)

Let $X = \overline{OG}$ = projection of OF' on x axis = $R \cos \theta$

Let $Y = \overline{OK}$ = projection of OF' on y axis = $-R \sin \theta$

Then, by geometry:

$$R = (\rho - A_c) - (X_0 - A_c) \cos \theta + (Y_0 - A_c) \sin \theta$$

Then:

X_c = DELX = CX = $RC \cos \theta$

Y_c = DELY = CY = $-RC \sin \theta$

where C converts array counts to Gradicon units. The negative sign for

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1/ The calibration procedure to be followed in measuring off-set quantities is described in Vol. III, Computer Program Documentation, Scanning Cursor Device, RADC Contract F30602-76-C-0443.

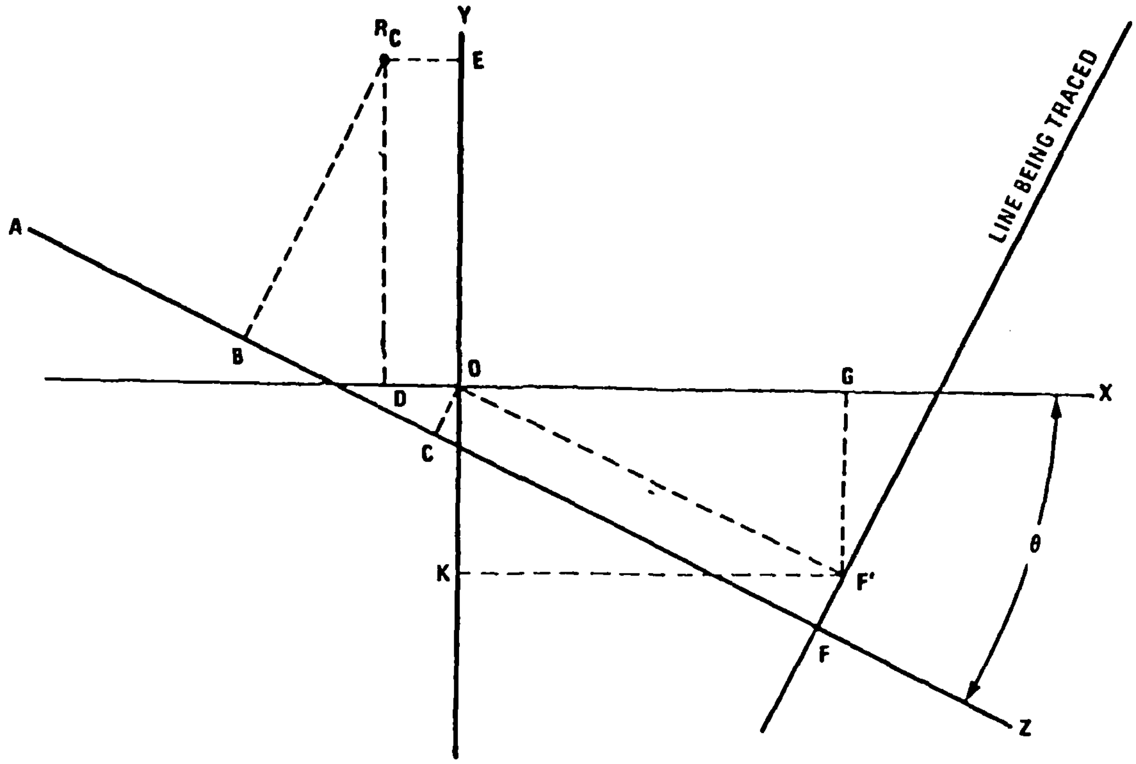


Figure 2-36. Geometry of Computer Correction Algorithm

Y_c results from clockwise rotation of θ being defined as positive. [The sine and cosine functions are obtained from trigonometric tables quantitized in one degree increments.]

The output data to the IMLAC is derived from these formulas via the following:

$$X_1 = X_g + X_c \quad . \; . \; . \; . \; . \; . \; . \; . \; . \text{ equation (1.3)}$$

$$Y_1 = Y_g + Y_c \quad . \; . \; . \; . \; . \; . \; . \; . \; . \text{ equation (1.4)}$$

where:

X_1 = X1 = corrected x data

Y_1 = Y1 = corrected y data

X_g = XWIN = X data from Gradicon

Y_g = YWIN = Y data from Gradicon.

Before transfer to the Imlac, these corrected values are modified to conform to a vector length restriction imposed on the data by the Imlac, as described in paragraph 2.2.4.2 - Vectoring.

2.2.4.2 Vectoring. In trace (or incremental) mode operation, the Imlac PDS-1D places the following requirements on the displacement in x and y between the last received data point and the current data point (these requirements are inherent in the LIS system):

a. both the x and y displacements must fall between -2 and +2 Gradicon output units, inclusive; and

b. the absolute value of at least one of the displacements must equal 2.

The data received by the HP computer from the Gradicon satisfies these criteria. However, due to the correction process, the output points may not. Therefore, the program must assure that these criteria will be satisfied.

The program assumes that over a space of two output points, the curve being traced can be approximated by a straight line, which passes through the last data point and the current data point. A new point on that line is found which, along the coordinate with the greatest displacement, has a displacement of two in the same direction as the original displacement. Since this is the coordinate of greatest absolute displacement, the other coordinate (when calculated) will have an absolute displacement of less than two and the initial requirements will be fulfilled. [This correction is made only when the cursor is in the Automatic, Incremental mode.]

2.2.4.3 Array angle calculation. The maintaining of the cursor array normal to the curve being tracked is a basic premise of the cursor operation. The array angle is controlled by a servo system which converts digital angular information from the computer into an analog drive voltage. The angle is transmitted to a D- to -A converter from the HP computer as a 10-bit word, each count being one degree. When the array is horizontal and in the center of its tracking limits, the output is 512 decimal or 1000 octal. Maximum clockwise rotation is 1023 decimal or 1777 octal; maximum counter-clockwise rotation is zero.

In calculating the array angle, the assumption is made that the angle whose tangent is the slope of the last two points tracked is a good approximation to the angle required. This assumption is justified as (in the extreme condition) when the line is tracked on the outer circle of the reticle, an angular error of 17 degrees will not cause the correction factor to shift by one array count. In the trace mode, where the cursor will have its real application, a curve with a radius of curvature of seven Gradicon resolution elements (5 mils, 0.13mm. in the normal operating mode) would be required to achieve this angle between points traced.

The slope of the line is determined directly from the coordinates of the last two points measured. The corresponding angle is determined from a tangent look-up table. The quadrant of the angle is determined from the sign of the x displacement and of the y displacement. At the start of the feature the array is set to the midpoint (512°) to allow maximum excursion, either clockwise or counter-clockwise. As each new angle is calculated, the new angle is chosen so that the array will have the least angular motion to reach that position.

In the incremental (trace) mode, the calculation of the slope from the last two points is subject to severe quantizing errors, since displacement in x and y will always be one or two Gradicon units. This could cause angle errors as great as 45 degrees. To minimize these errors the average of the last eight angles measured is used to orient the array. The remaining fluctuation in angle is within the allowable limits necessary to maintain the required accuracy.

2.2.5 Computer Flow Diagram

The basic sequence of computer operations within an execution cycle is delineated below.

a. Wait for Gradicon data ready flag.

b. Transfer status word, x-word, and y-word in sequence to the HP in binary 16-bit parallel format.

c. Test status word for selected mode (manual or aided track).

d. Read the video processor array output count.

e. Calculate corrected x and y values.

f. Modify x and/or y to meet $\Delta x,y = 40$ microns data valid condition.

g. Send data ready flag to Imlac.

h. Transfer status word, x-word, and y-word in sequence to the Imlac under control of the Imlac word select lines.

i. Calculate new array rotation angle.

j. Transfer new angle command to video processor.

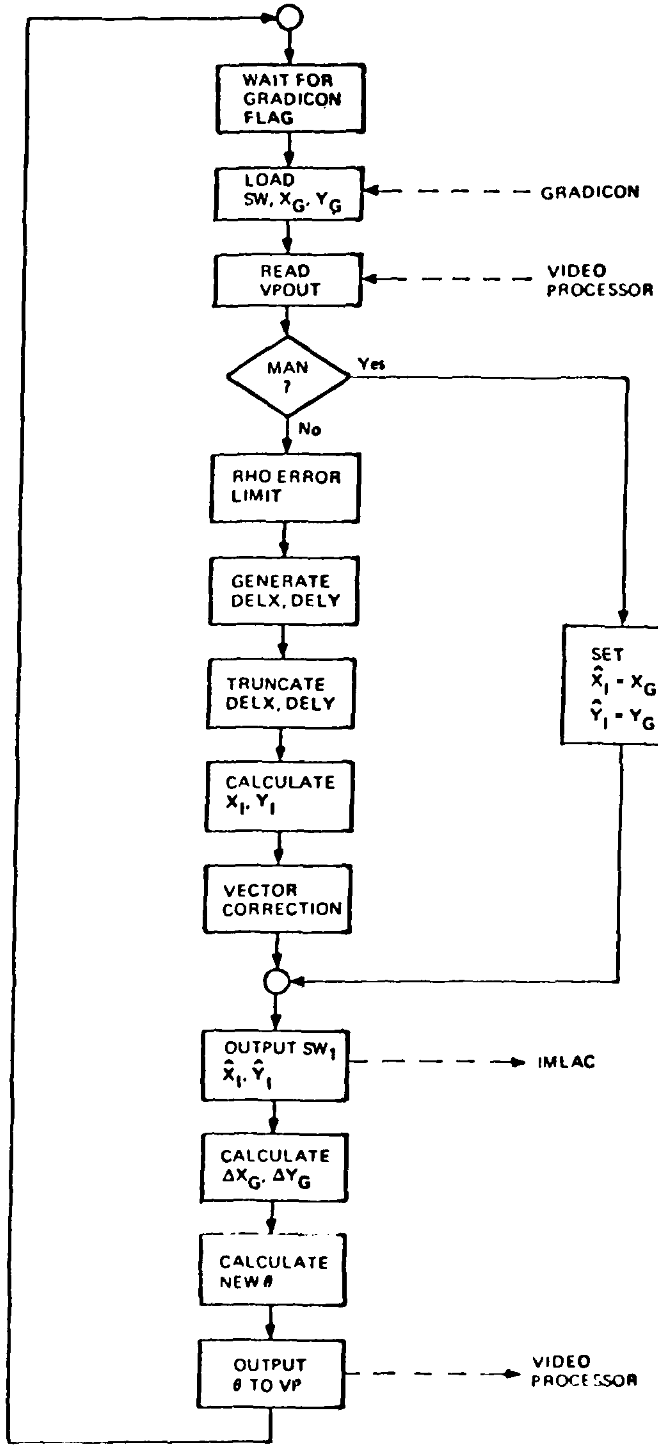
k. Wait for next Gradicon flag.

The execution cycle time of the aided-trace program is 750 microseconds, allowing an average aided-trace digitizing rate in excess of 10 in/min.[1] Figure 2-37 illustrates the flow diagram of the running program of the scanning cursor aided-track system. Marginal notations define symbols appearing in the sequence of operations.

2.2.6 Measured Performance Characteristics for Aided-Track Digitizing

Two scanning cursor systems were constructed and installed in an LIS environment. They were also tested at an engineering level. The first advanced developmental model was designed for use on backlighted graphic material in which transmissive changes were used for feature detection; the second was designed for use on both backlighted and opaque materials. In the opaque mode of operation, light sources contained within the aided-track cursor illuminated the region of interest; reflective changes developed the required array signal. A summary of the measured performance of the systems compared to a precise manual trace of the same features is shown in Table 2-9.

1/ Scanning Cursor Device, Final Technical Report, RADC-TR-78-211, October 1978.



X_G, Y_G	GRADICON DATA
X_I, Y_I	CORRECTED DATA
$\hat{X}_I$, $\hat{Y}_I$	VECTORED DATA TO IMLAC
ΔX_G	$= (X_{G1} - X_{G2})$
ΔY_G	$= (Y_{G1} - Y_{G2})$
DELX, DELY	X, Y CORRECTION TERMS
RHO	ARRAY COUNT

Figure 2-37. Computer Flow Diagram

Table 2-9

Comparison of Manual and Aided-Track Tracing Performance[3]

		Manual	Aided-Track Transmissive	Aided-Track Reflective[1]
Tracing Speed in/min		3.72	10.7	9.9
Overall Accuracy[2]	Average RMS Error-mils	3.56	1.54	2.36
	Error dispersion-mils	10.2	4.7	8.6

1/ Statistical performance parameters for the Reflective Scanning Cursor include spurious corrections caused by environmentally-induced noise in the array output

2/ Accuracies shown include error contributions from all sources, including inherent table accuracy

3/ References: Final Technical Report, Scanning Cursor Device, RADC-TR-78-211, October 1978; and Final Technical Report, Reflective Scanning Cursor, (To be issued.)

2.3 COMMERCIAL TABLE VENDOR SELECTION

2.3.1 Overview

Identifying the commercially available digitizers was an extremely time consuming task. The goal of this task was to identify all of the unique, free cursor, digitizing tables which satisfied the Statement of Work requirements of (1) a minimum of 40 by 60 inch (1067 x 1524mm) digitizing area, (2) accuracy of ± 0.005 inches (± 0.13mm), and (3) ± 0.60 inch (0.025mm) resolution. In order to complete the task, all of the available technical literature (i.e., product briefs, technical magazines, and the Auerbach reports) were reviewed and a list of candidate companies was generated. The project staff contacted the candidate companies in order to collect the following information:

a. identification of the companies which build/manufacture their own tables;

b. identification of the table builders for the OEM companies or build commercial digitizing systems; and

c. identify any OEM companies which modify their purchased tables in a way to change the characteristics.

Following this approach, the project staff was able to identify every company which builds or modifies digitizing tables. Therefore, all tables which have different characteristics or interface requirements and meet the specifications would be included in this study.

2.3.2 Candidate Manufacturers Analysis

The following is a list of the candidate companies which were researched to identify digitizing table manufacturers.

ALTEK	Calcomp
Bartlett Associates	Data Automation
CALMA	Dicomed
Eastronics	GTCO
DBA	Iom-Towill
Electrak	Kelsh
H. Dell Foster	M & S Computing
Aristographics	Scriptographics
Bendix	Summagraphics

Laser Scan LTD.	Autotrol
Tridea Electronics	K & E Company
Numonics	Computervision
Spatial Data Systems	Synercom Technology
Talos	Data Technology
Wang	

Although the project staff realized that some of these companies did not manufacture digitizing tables, they still contacted them with the idea that these companies may be able to identify other candidate companies which were not included in our original list.

Out of the 29 companies researched, only seven companies were identified as table manufacturers. The remaining 22 companies were eliminated because of at least one of the following reasons.

a. They are a marketing company which represents a table manufacturer.

b. The digitizer they market is not a table with a free cursor but rather a scanner or image projection digitizer.

c. They sell commercial digitizing systems that use one of the manufacturer's tables. None of these companies claim to make any modifications to the original tables.

d. Some of the companies are no longer in business - they have been bought by another company, or changed their name. Examples of these are:

    1. Eastronics was bought by ALTEK.

    2. The Bendix patent was sold to Scriptographics who changed their name to Summagraphics.

    3. Talos bought Calcomp.

In our plan, we intended to list all candidate companies associated with related information such as table manufacturers, system houses and the manufacturer of their tables, or types of digitizers available. However, for reasons of their (the vendor's) own, most of the companies which do not manufacture digitizing tables would not officially tell us where they purchased their tables. Some would only tell us that they purchased them; they would not specify from whom. The companies who did provide specific information asked that they not be quoted in a formal document. The most favorable alternative was to have all of the vendors tell us that they did indeed purchase their tables from one of the seven manufacturers which we had identified. This was verified by checking with the manufacturers and a visual comparison of the manufacturer's table against pictures of the commercial digitizing systems. When this review was completed, the project staff was satisfied that all digitizing table manufacturers had been identified.

2.3.3 Digitizing Manufacturers

Of the seven table manufacturers identified, only Wang stated that they were unable to furnish a large table that would satisfy the SOW requirements. Tables 2-10 through 2-15 provide the general characteristics of the six table manufacturers which could meet the requirements.

During our initial contact with these companies, we explained the purpose of the study and requested their cooperation. All the companies promised complete cooperation.

Table 2-10

Digitizer Manufacturer

Manufacturer:	ALTEK Corporation 2150 Industrial Parkway Silver Springs, MD 20904 (301) 622-3907
Table Name and Models:	Datatab Model 1, 2 or 3
Table Size:	42 x 60 in (1067 x 1524mm)
Resolution:	Model 1 = 0.01 in. (0.25mm) Model 2 or 3 = 0.001 in (0.025mm)
Accuracy:	Model 1 = ± 0.02 in (± 0.51mm) Model 2 = ± 0.005 in (± 0.13mm) Model 3 = ± 0.003 in (± 0.07mm)
Sample Rate:	100 points/second
Standard Cursor:	1 or 16 buttons
Backlighting:	Optional
Microprocessor:	Optional

Table 2-11

Digitizer Manufacturer

Manufacturer:	Aristo Graphics Corporation 53 South Jefferson Road Whippany, N.J. 07981 (201) 887-2852
Table Name and Model:	Aristogrid 100; GRT 109
Table Size:	39 x 59 in (1000 x 1500mm)
Resolution:	0.001 in (0.025mm)
Accuracy:	± 0.004 in (± 0.1mm)
Sample Rate:	160 points/second
Standard Cursor:	5 or 25 buttons
Backlighting:	Not Available
Microprocessor:	Standard

Table 2-12

Digitizer Manufacturer

Manufacturer:	(Data Automation)[1] Interface Electronics, Inc. 21134 Bridge Street Southfield, Mich. 48034 (313) 352-8820
Table Name and Model:	Datatrak
Table Size:	42 x 60 in. (1067 x 1524mm)
Resolution:	0.001 in. (0.025mm)
Accuracy:	$\pm$ 0.005 in. ($\pm$ 0.13mm)
Sample Rate:	150 points/second
Standard Cursor:	6 or 16 buttons
Backlighting:	Optional
Microprocessor:	Optional

NOTE 1: The characteristics of the Datatrak table were originally obtained from Data Automation. Shortly after we received this data, the company initiated a major reorganization and no further data could be obtained for this study. While writing this report, we learned that Interface Electronics, Inc. is now building and maintaining these tables.

Table 2-13

Digitizer Manufacturer

Manufacturer:	GTCO Corporation 1055 First Street Rockville, MD 20850 (301) 279-9550
Table Name and Model:	Datatizer
Table Size:	42 x 60 in. (1067 x 1524mm)
Resolution:	0.001 in. (0.025mm)
Accuracy:	Standard = ± 0.01 in. (± 0.25mm) Optional = ± 0.005 in. (± 0.13mm) Special = ± 0.003 in. (± 0.07mm)
Sample Rate:	Standard = 25 points/second Optional = 50 points/second
Standard Cursor:	1, 5 or 16 buttons.
Backlighting:	Optional
Microprocessor:	Optional

Table 2-14

Digitizer Manufacturer

Manufacturer:	Summagraphics 35 Brentwood Avenue, Box 781 Fairfield, CT 06430 (203) 384-1344
Table Name and Model:	Summagrid, SG-60-BL
Table Size:	42 x 60 in. (1067 x 1524mm)
Resolution:	0.001 in. (0.025mm)
Accuracy:	± 0.005 in. (± 0.13mm)
Sample Rate:	100 points/second
Standard Cursor:	1, 4, or 13 buttons
Backlighting:	Optional
Microprocessor:	Optional

Table 2-15

Digitizer Manufacturer

Manufacturer:	Talos Systems, Inc. 7419 East Helm Drive Scottsdale, Arizona 85260 (602) 948-6540
Table Name and Model:	The Standard One^{TM*}
Table Size:	44 x 60 in. (1118 x 1524mm)
Resolution:	0.001 in. (0.025mm)
Accuracy:	$\pm$ 0.005 in. ($\pm$ 0.13mm)
Sample Rate:	100 points/second
Standard Cursor:	12 or 16 buttons
Backlighting:	Optional
Microprocessor:	Optional

*TM - Registered Trademark Name.

SECTION 3. ANALYSIS OF HARDWARE INTERFACE REQUIREMENTS

3.1 INTRODUCTION

The majority of presently available table digitizers output encoded coordinate points in a time stream mode (i.e. points per second). Gradicon data, as discussed in previous sections, was spatially outputted (i.e. points per inch). This section of the report will discuss the application of the existing scanning cursor hardware and software to time-based digitizers. Particular attention is focused on the interface area and the consequent implications on I/O programming, expected over-all system performance, and general system considerations. Compatible interfaces available from several candidate digitizer manufacturers are described and estimated modification costs to operate the scanning cursor system with these tables are presented for the selected configuration.

3.2 GENERAL CONSIDERATIONS

The following discussions are based on time-stream digitizing at 200 points per second. While this rate is somewhat higher than generally given in vendor specifications (50 to 160 points per second), leading table manufacturers indicate that this rate, depending on the type of interface, is presently obtained from their tables. Design specifications established for the reflective and transmissive scanning cursor systems, given in Table 3-1, are not affected by the table encoding principles and are applicable to the equipment considered in this section of the report.

3.3 COMPARISON OF TIME-STREAM AND SPATIAL-GRID ENCODING

In time-based digitizing, the tracing velocity will determine the spatial distance separating two consecutive coordinate points in an inverse manner (i.e. the higher the velocity, the fewer the number of points which will be generated to define the traced feature). If the output device used to reproduce the feature relies on point-to-point vectoring, sizeable deviations can occur if excessive speeds are maintained in tracing feature curvatures. Fortunately, the tracing operation is inherently self-regulating; the manual-visual coordination required to trace curvatures accurately necessitates lowered tracing speeds, thus providing a greater number of

Table 3-1

Design Parameters for the Aided-Track Cursor System
(Transmissive and Reflective)

Error Correction range	$\pm$ 30 mils (0.76 mm)
Accuracy	$\pm$ 2 mils (0.04 mm)
Line range width	4-20 mils (0.1 - 0.51 mm)
Array operating specs (nominal).[1]	64-elements on 2-mil (0.05 mm) centers; Sample rate 15 KHz; scan rate-217 scans/sec.; scan period - 4.6 ms

1/ Array scan rate determines the integration time of an element in generating the signal modulation achieved; this rate is adjusted to available light levels. Specifications given in this table allow operation in the reflective mode and the Gradicon table backlighted mode.

points in defining this portion of the feature. Digitizer manufacturers rely on this operator limitation to produce "reasonably accurate" reconstruction of the graphics. A direct comparison of output quality from spatial and temporal coordinate digitizers is therefore difficult to make unless some assumptions can be made regarding tracing velocity and the sampling process.

To provide a basis for comparison between time-stream and spatial-grid digitizer operation, the tracing parameters shown in Table 3-2 are used. These parameters result from measurements made during station tests with the reflective and transmissive scanning cursor systems using typical hydrographic features. Manual tracing times depend on the required degree of accuracy of the output plots and can vary. The speeds shown were the result of precision tracing in the manual mode in which RMS tracing errors were kept to within $\pm$ 4 mils (0.1 mm).

The equivalent time sampling rate for the Gradicon system is derived from the use of a 1.56 mil (0.04 mm) spatial grid; coordinate points are encoded at the constant spatial rate of 641 points per inch. (A point consists of an X,Y pair of values and an accompanying status word.) Assuming these speeds apply to table digitizers generally, and are independent of encoding techniques, Table 3-3 illustrates the comparative ability of the digitizers to produce high accuracy reproductions of the traced feature in terms of spatial sampling rates. Since the fidelity of the output is directly related to the number of samples used in the reconstruction, a higher number of spatial samples increases the output resolution. While these are average figures, they compare favorably with the spatial sampling distance of the Gradicon system. Hence, the output copy can be expected to be of equal or better quality than generated by the Gradicon unit, all other factors being equal. It may be noted that in order to obtain a spatial sampling equal to that of the Gradicon table, a time conversion rate of 110 pts/sec would prove adequate at the average tracing speed of the aided-track mode.

3.4 OUTPUT DATA SYNCHRONIZING

The data in the following three subsections pertain to Table Synchronization, Array Synchronization, and Asynchronous Data Generation as they relate to output data synchronizing.

3.4.1 Table Synchronization

All digitizing table interface options provide the user a signal defining the conversion interval thus allowing external devices to be synchronized to the table system clock. Since it is a commonly available

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Table 3-2

Digitizing Tracing Parameters

Tracing mode	Average tracing speed	RMS error	Equivalent time sample rate
Manual	3.72 in/min (95 mm/min)	± 3.56 mils (± 0.09 mm)	40 pts/sec
Aided-track	10.3 in/min (262 mm/min)	± 1.45 mils (± 0.04 mm)	110 pts/sec

Table 3-3

Comparison of Spatial Sampling

	Average Spatial Sample Rate (pts/in)	
	Manual	Aided-Track
Equivalent time encoding (pts/sec)	3225	1165
Gradicon spatial encoding (pts/in)	641	641

NOTE: Conversion of points/sec to points/inch for time encoding assumes a tracing velocity of 3.72 in/min (95 mm/min) and 10.3 in/min (262 mm/min) for the manual and aided-track cases, respectively, and a table conversion rate of 200 pts/sec.

signal, it is desirable to use the table to initiate the start of the array scan cycle, In this case, the array integration time is fixed by the selected table conversion time and effects the output level of the array.

During the conversion interval the array remains active and integrates incident light until the photosensitive diode junctions of the individual elements are recharged by the sampling process. If the table conversion time is changed, the array signal levels will also vary. For example, if the array operating conditions are optimally set for the maximum table conversion rate, the array will tend toward saturation at lower conversion rates because of the increased integration time. In the extreme, an imaged feature would not produce a usable signal from the array. Conversely, setting array detection conditions at a lower table conversion rate will result in decreased signal levels at higher conversion rates.

A timing diagram for synchronizing the array output count to the table conversion period is shown in Figure 3-1. To operate to the maximum conversion rate of 200 conversions per second, the array scan time would be fixed at 4 ms (13.8 KHz sample clock) and would remain constant for all conversion rates [T_T] selected. In the limiting case, the table conversion period would approach the array scan time to produce usable output signal levels.

The input video circuitry provides the capability of compensating for changes in background pedestal level by a unique self-balancing feedback amplifier. This amplifier is arranged to maintain a constant average output level of background plus signal without varying its gain. A subtractive level is generated to cancel the effect of background variations if the input signal lies in the linear range of the amplifier. However, if signal saturation occurs at the array due to excessive exposure time, no feature detection can be sensed and no balance condition will be found. A large range of change in table conversion time can be accommodated as long as a detection peak exists in the array output.

A block diagram of the amplifier is shown in Figure 3-2. The balance amplifier output is passed through a low-pass filter acting as an averaging circuit. The averaged output is compared to a reference voltage. This difference voltage is used to rebalance the amplifier under changing input conditions for the average output voltage to be equal to the reference. Thus, if the reference voltage is established for the condition of lowest signal-to-noise ratio that results in a positive, unambiguous signal detection, the balance amplifier will attempt to maintain the same waveform (i.e. the same average value) for all other conditions. The self-balancing feature also provides a tolerance range to variations in illumination source brightness. A detailed description and test results obtained with the amplifier may be found in RADC Technical Report 79-2, Scanning Cursor Techniques II.

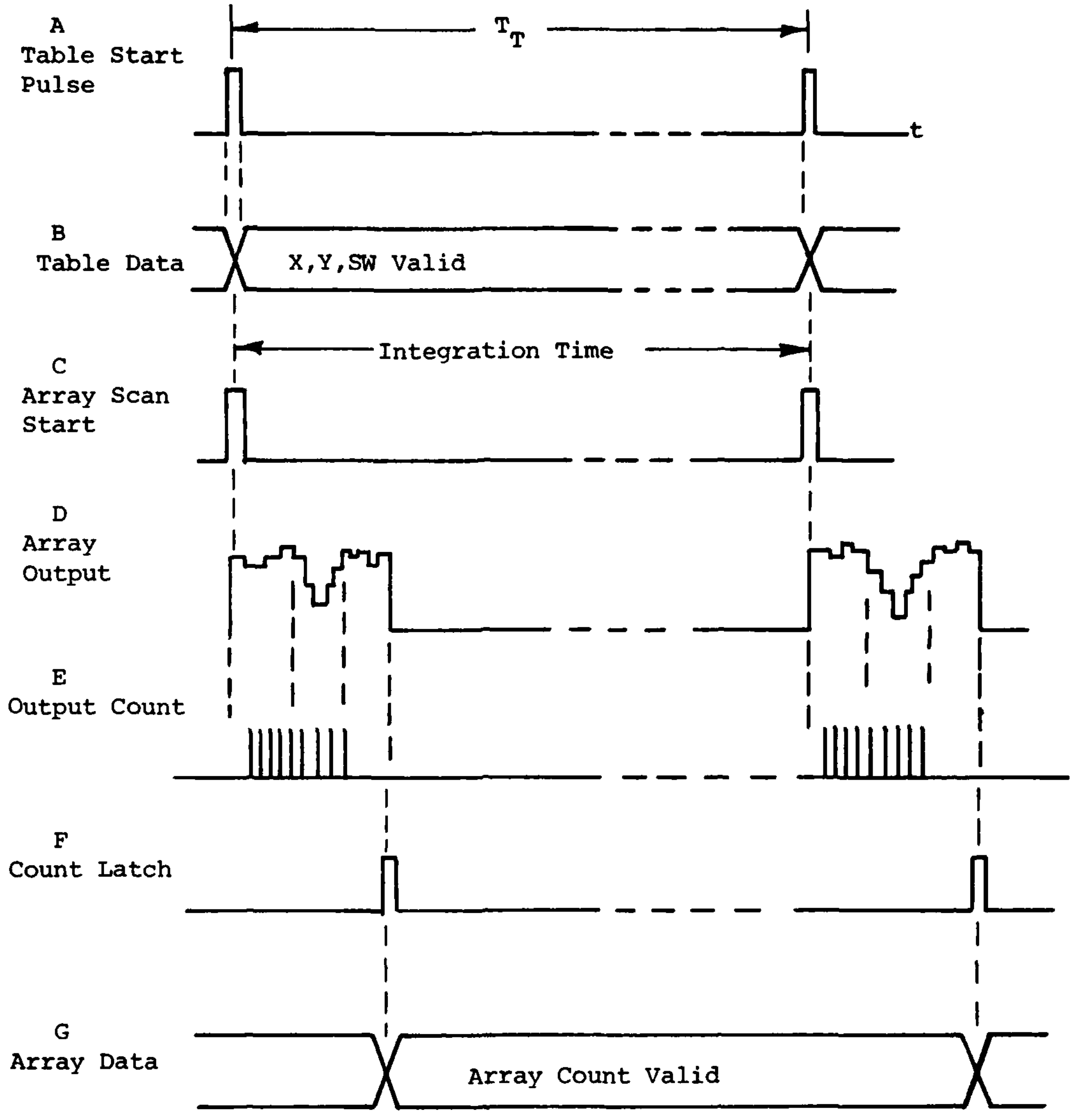


Figure 3-1. Timing Diagram for Array Scan Start Synchronized to Table Conversion Time

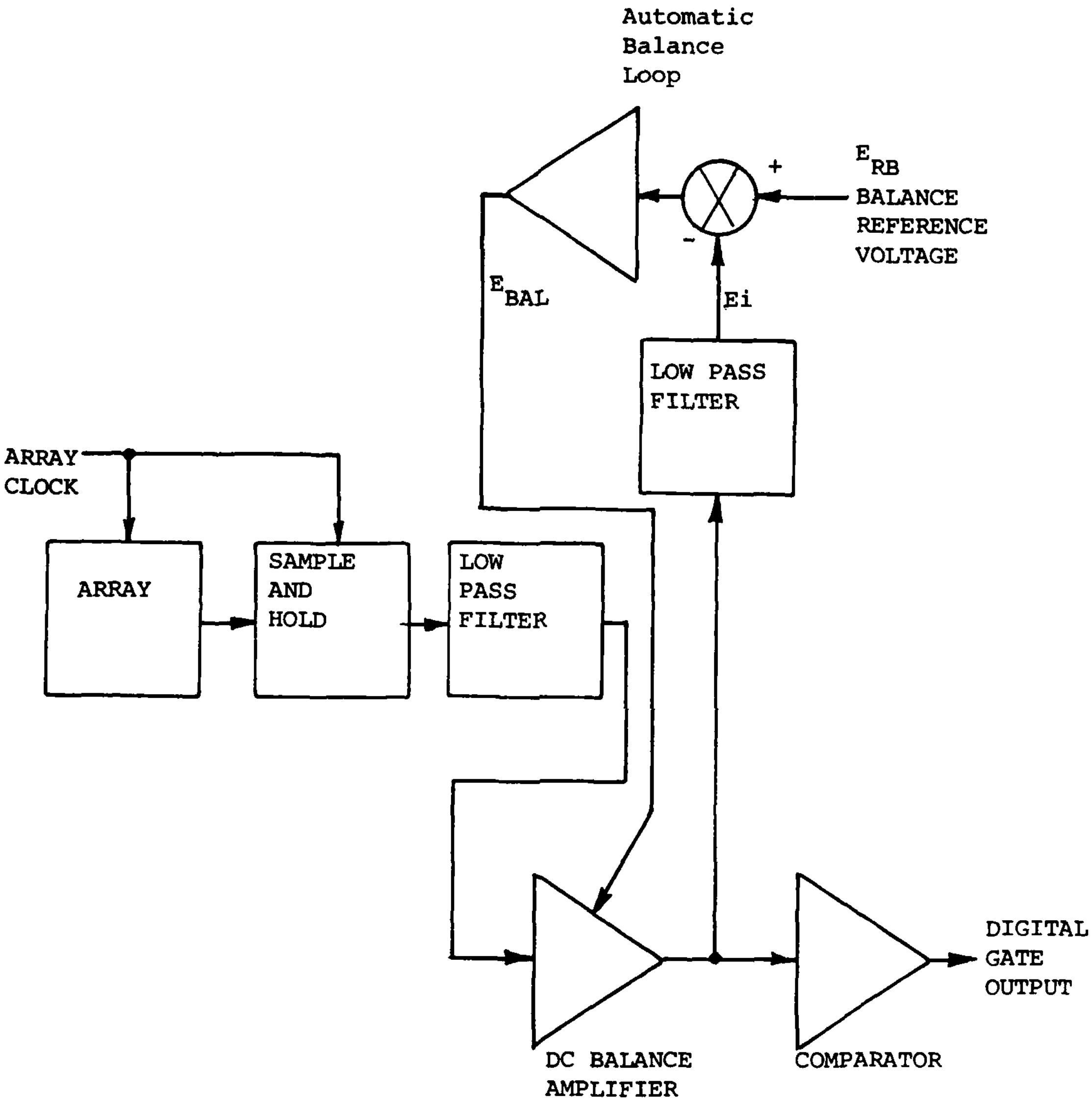


Figure 3-2. Block Diagram of the Analog Array Signal Processing to Adjust DC Balance in Response to Changes in Manuscript Background Level

3.4.2 Array Synchronization

A second synchronization scheme would provide an array scan synchronizing signal to initiate a transfer of a coordinate point from the digitizing table, where such provision is made by the table manufacturer. For this case, the array integration time would remain constant; this scheme would effectively fix the table conversion frequency to an array scan rate not to exceed the table manufacturer's specified maximum data transfer rate. (It should be noted that this method of operation is not an option generally provided by manufacturers.)

The timing requirments to synchronize table transfers to the array scan is shown in Figure 3-3. It should be noted that while table data can be transferred at the start or end of each array scan interval, a variable delay dependent on where the feature is detected by the array is presented in the instants at which an array count is generated and the table coordinates are digitized. This translates to a spatial displacement in actual cursor position from the position at which the array count error is derived. This delay is discussed further in Section 3.5.

3.4.3 Asynchronous Data Generation

Array count data can be asynchronously generated with respect to the table coordinate conversion rate without serious degradation of the capability of the system if at least one array scan is present within the table conversion period to provide correction factors. The Gradicon-Scanning Cursor configuration was operated in this mode, the latest array sample information being entered into the computer following each data transfer from the table. The advantage of asynchronous operation is in the ability to independently adjust the scan period to optimize array signal levels and the number of error samples generated during the table conversion interval.

3.5 ARRAY SCAN DISPLACEMENT ERROR

Since a finite time is required to integrate the light level on the array to develop adequate electrical signal levels, a variable time displacement will generally exist between the time the table encodes a coordinate set and the time at which the array generates a correction count. The maximum displacement could approximately equal the integration interval since no new correction terms are available until the end of this time. The position at which the array correction count is valid (see Figures 3-1 and 3-3) depends on where the feature is detected (i.e. at what point of time within the scan period the array count is stopped). This time displacement can be translated to a spatial displacement between the encoded point and the point at which array correction terms are derived. If the table is assumed to encode the point (X1, Y1), a synchronous array output count can occur displaced in distance by $\pm \Delta S$, where

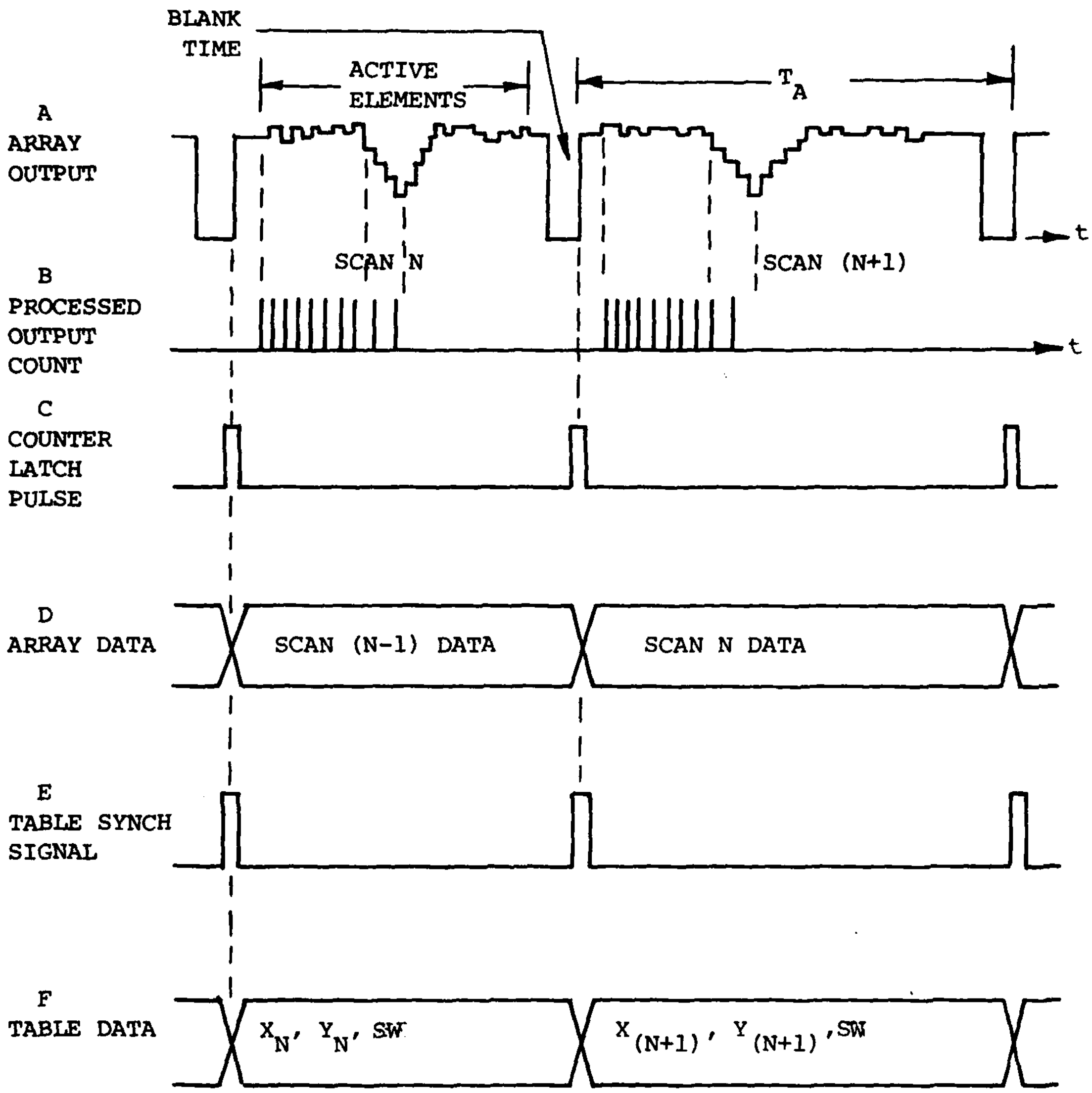


Figure 3-3. Timing Diagram for Table Output Synchronized to Array Scan Time

$$\Delta S = \pm \nu T$$

ν = tracing speed in/sec

T = array integration time/sec.

This displacement is independent of the table conversion period.

The assumption is made that normal tracing errors accumulate in a relatively smooth, continuous manner so that a correction factor is valid for a small region about the point for which the factor is generated. Arbitrarily, the lineal range over which the correction factor is defined to be applicable is

$$|\nu T\ A| \leq .0015 \text{ inch } (0.038 \text{ mm}).$$

This variation appears to have a negligible effect on overall correction accuracy which can be achieved with the scanning cursor system, based on measured test results. Based on an A/T trace velocity of 10 in/min (254 mm/min) and a 5 ms integration time, the displacement of data in the Gradicon system was in the order of 0.84 mils (0.02 mm). For an array period of 5 ms, the allowable maximum tracing speed would become

$$\nu \leq \frac{1.5 \times 10^{-3}}{5 \times 10^{-3}} \leq 0.3 \text{ in/sec } (7.62 \text{ mm/sec}) \text{ or } 18 \text{ in/sec } (457 \text{ mm/min}).$$

This velocity is about twice that measured in tests with the scanning cursor system.

3.6 INTERFACE SELECTION

The following criteria for interface selection were the primary factors in specifying the interface between the digitizer and the scanning cursor system.

a. Direct hardware compatability with standard computer inputs/outputs (I/Os). An objective was to avoid any customized hardware.

b. Commonality as an optional interface offered by a majority of manufacturers. This was aimed at permitting the widest choice in selection of the digitizer equipment.

c. Transfer speed of data through the interface. Introducing the scanning cursor system between the digitizer and the ultimate peripheral device adds another interface and decreases the available transfer time by the processing time of the intermediate computer.

3.6.1 Interrupt vs. "Wait-Loop" Data Inputting

In general, the inputting of data from a peripheral device via an interrupt program is designed to service slower speed devices on an "as-needed" basis, permitting greater computer efficiency. The "wait-loop" inputting concept addresses the peripheral devices to request a data transfer; the computer program will stop until the transfer has been completed. Whether one inputting method has an advantage depends in part on the timing and duty cycle of the computer between data transfer times.

Figure 3-4 shows the processing interval required to derive a single corrected coordinate point, including times for transferring data to and from the scanning cursor computer. A maximum digitizer conversion period of 5 msec (200 points/sec) is assumed, with a 1 msec computer processing time. Input/output transfer times are estimated from program instruction times for effecting a transfer. The figure further assumes that the array scan start is synchronized to the peripheral data ready instant. For this case, it can be interpreted that a maximum array scan time in the order of 4 msec will fulfill the timing requirements. This scan time also allows an adequate signal integration time to develop a well defined feature detection interval across the array elements.

A table conversion rate of 200 points per second is, at this time, a "state-of-the-art" maximum rate. The "wait-loop" transfer program of the existing software encompasses this rate. If future development results in increased maximum rates, two directions can be followed to maintain the scanning cursor timing compatibility; the scanning cursor program execution time can be reduced, or, adjustments can be made to decrease the array integration time to increase the error sampling rate. The limitation to integration time lies in the available signal-to-noise ratio at the array output. Noise contributions stem primarily from variation in background illumination, environmental noise, and variations in array element-to-element sensitivity. Also, signal levels can vary with the spectral characteristics and type of manuscript material.

3.6.2 RS232 Serial Interface Considerations

In its present operation, the cursor array is scanned asynchronously, with the last value of the array count transferred to the computer on request. If data generated by the array and the table are synchronized, an additional interval must be included to allow the array to scan its elements

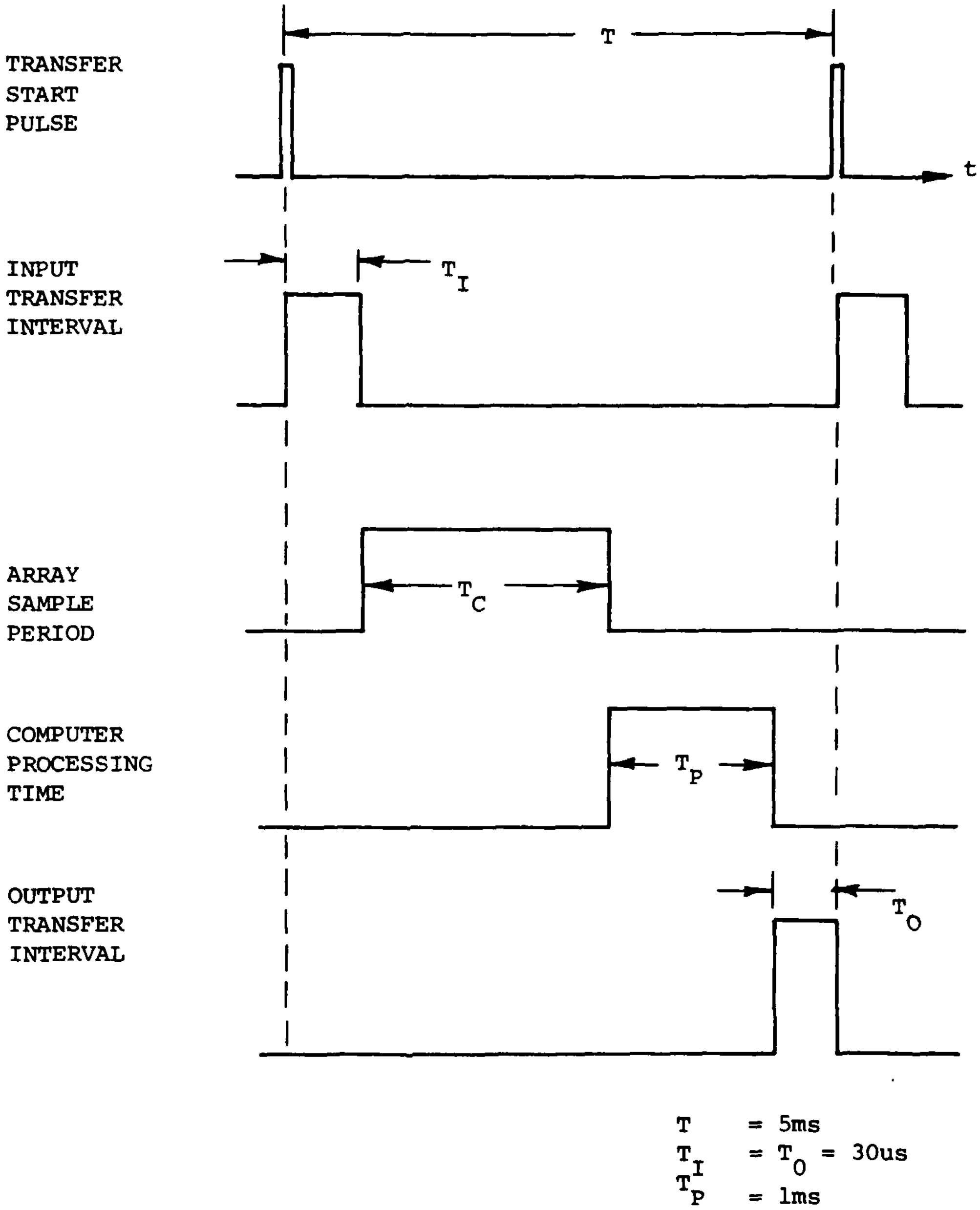


Figure 3-4. Timing Diagram for Processing a Single Coordinate Pair in a Table Synchronized Mode

either prior to, or following, transfer of an encoded coordinate point.

The determination of baud rate for a serial transfer of data is based on the following time sequence for transferring a single coordinate data point from the digitizer to the HP computer used in the scanning cursor system and then to the digitizing station computer after the data is corrected (reference Figures 3-5 and 3-6) assuming that a valid array count is available for each coordinate value generated by the table. (The time period for scanning the array is neglected.) The baud rate is determined from

$$B = \frac{N + OH}{T_T}$$

B = baud rate (bits/sec)

N = total number of data bits transferred

OH = total number of over-head bits transferred

T = minimum time between data points

T_T = data transfer time

T_P = scanning cursor system processing time

The scanning cursor system should be capable of sustaining the maximum table conversion rate of 200 points/second; for this condition,

$$T = 2\,T_T + T_P = 5.0 \text{ millisec.}$$

The scanning cursor system processing time, T_P, is in the order of 1 millisec as it presently runs. The required rate T_T, is then calculated as 2.0 millisec.

If we further assume the x,y and the status word are each of 16-bit length, then

$$N = 48 \text{ bits.}$$

This represents 6 blocks of RS232 characters, each block composed of 8-data bits plus 3-bits for start, stop, and parity; therefore an additional 18-bits are necessary as over-head. Under these considerations the required baud rate would be,

$$B = \frac{(48 + 18)}{2} \times 10^3 = 33.0 \text{ Kbaud.}$$

This rate, which exceeds standard RS232 rates, is that necessary in order not to compromise the digitizing speed of the table. (The Talos table, for example, specified to have a maximum conversion rate of 100 coordinate

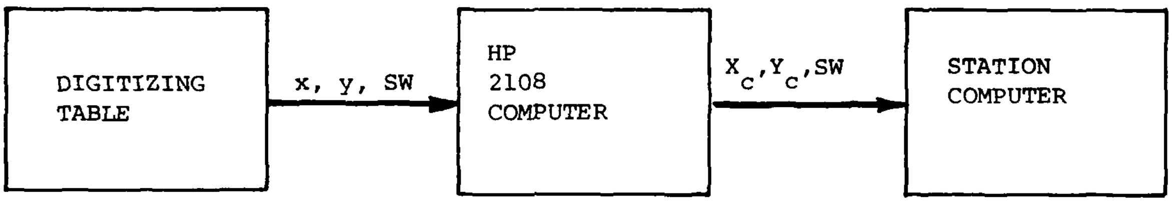


Figure 3-5. Data Transfer Sequence

Timing sequence shown for maximum transfer rate:

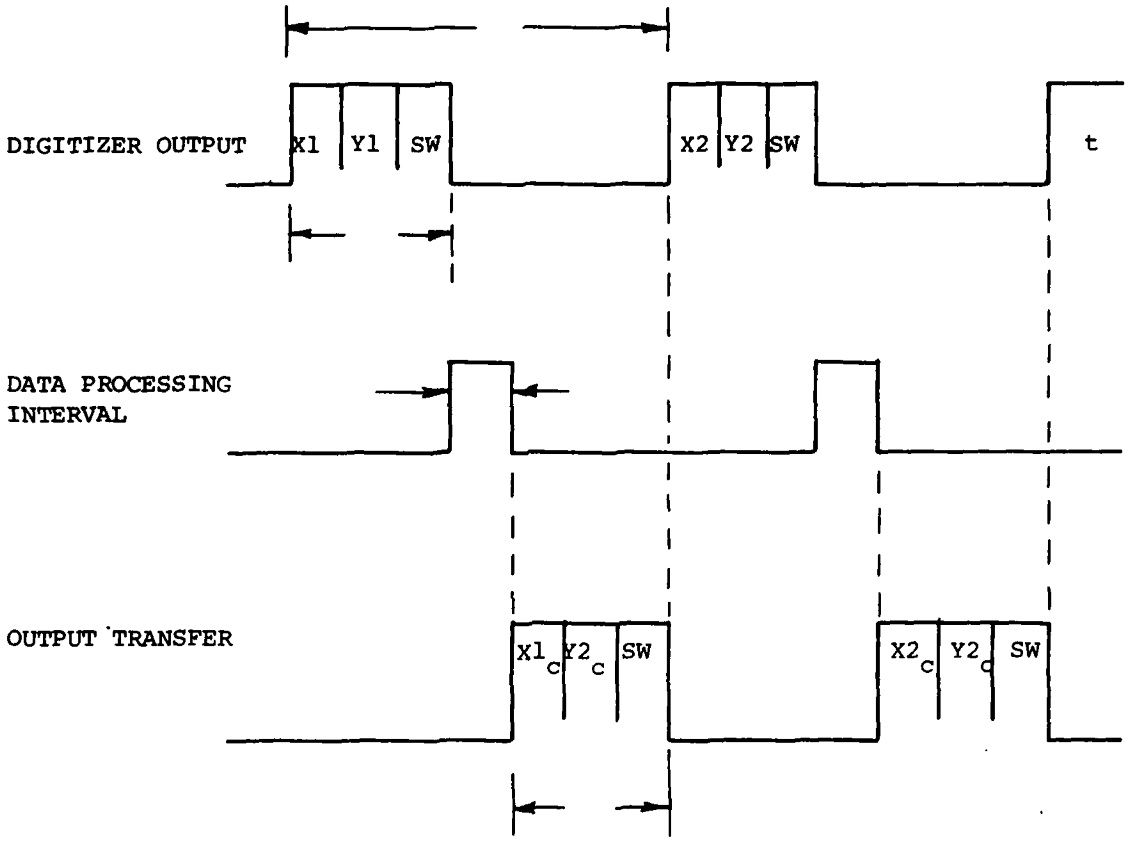


Figure 3-6. Serial Data Timing Diagram

pairs per second, can only achieve rates of 60 to 75 pairs per second when used with an RS232 interface because of this baud rate limitation.)

If we assume that the transfer intervals T_T are consistent with an RS232 rate of 9.6 Kbaud (this is the rate given for the HP12968A Asynchronous Communications interface board), the total transfer time $2T_T$ for transfer of 66-bits is then 13.76 ms. Here again the processing time T_P is fixed at 1 ms. (The array scan time is a variable period determined by the sample clock frequency selected. At the maximum rate of 1 MHz, the array scan time is 69 μs, which can be neglected.) Hence, the minimum conversion time (and consequently, array integration time) is 14.76 ms; this results in a maximum conversion rate of 68 points per second. (For a maximum RS232 bit transfer rate of 19.2 Kbaud the conversion rate would become 127 points per second, still under the anticipated maximum table capability of 200 points per second. According to HP, board revisions and some customizing of the the interface would be required using the HP12968A board to transfer data at this rate.)

A summary showing the maximum permissible conversion rates for the various baud rates is shown in Table 3-4.

3.6.3 Bit-Parallel, Sequential Word Transfer

To remove the speed restrictions imposed by the serial bit transfer, a 16-bit parallel transfer of each word of an encoded point (X,Y, and Status Word) is considered. For this case the transfer time for a word is determined by the I/O execution time of the computer, which is in the order of 20 μs/word. A complete set of coordinate data is transferred in 60 μs. In synchronized operation, if the array integration time at its present equals 5 ms period, a minimum conversion time of 6.12 ms can be realized; data can be converted by the table at 163 points per second. This conversion rate exceeds present manufacturers specifications.

Digitizer manufacturers contacted during the course of this contract all provided some optional parallel bit interface configuration. Parallel outputs are available in separate X, Y, and SW registers, or as sequentially transferred words using a common output register. In most cases control line signals are proven useful for synchronizing either the table conversion cycle or the array scan period. As a consequence of this data transfer analysis, an interface document was prepared and forwarded to major vendors for response. The specifications are contained in Appendix A.

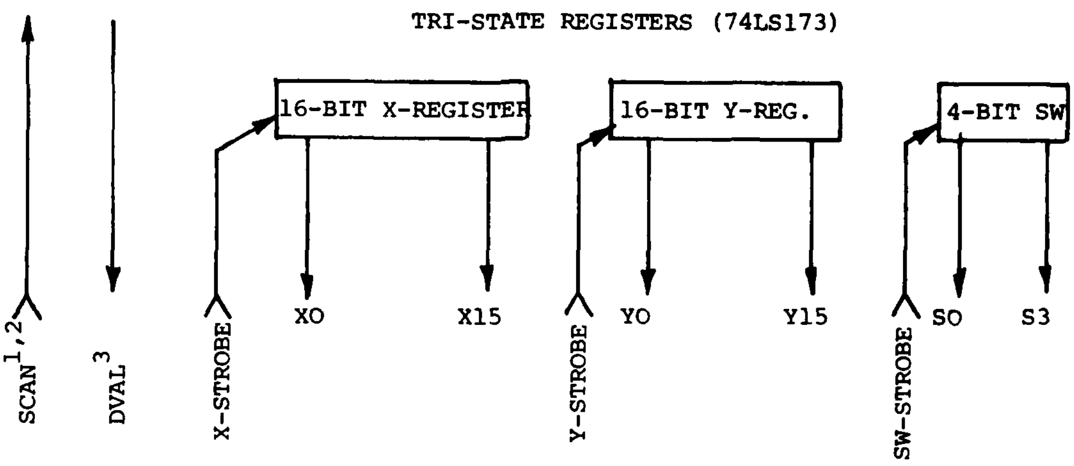
The following pages outline parallel bit output interfaces available from some major table vendors. All of these can be applied to meet the timing requirements discussed. Figures 3-7 through 3-10, inclusive, show interface configurations and notes on the recommended interface option of the designated manufacturer.

Table 3-4

Digitizer Conversion Rate versus Baud Rate

Baud Rate (Kbaud)	Conversion Rate (points/sec)	Comment
9.6	68	Maximum rate of HP-I/O interface.
19.2	127	Maximum standard RS232 baud rate.
33.0	200	Baud rate required for maximum digitizer conversion rate.

This table indicates that standard RS232 transmission rates sets limits that are below the maximum specified rates of a number of available tables.

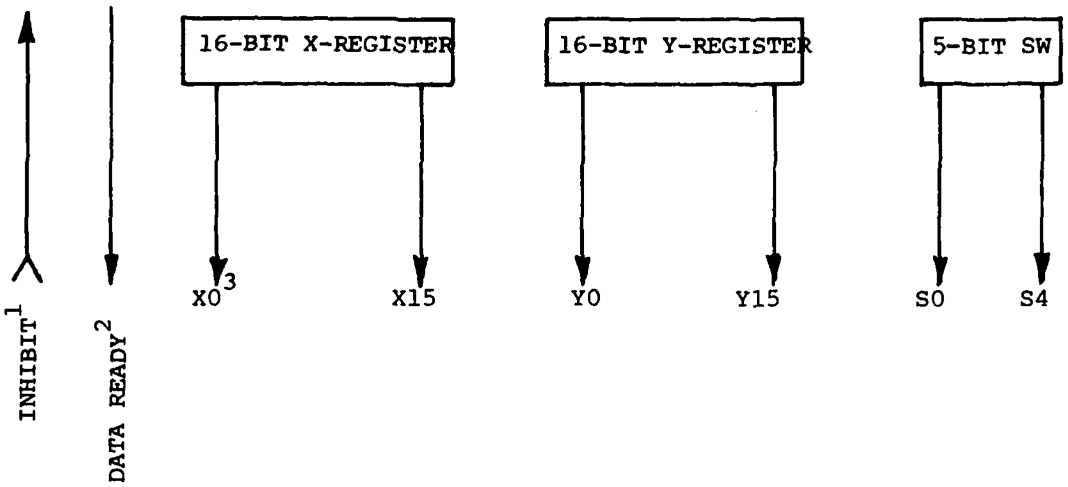


1/SCAN can be used to synchronize table output to array scan start.

2/SCAN HIGH results in continuous readings at factory set rate of 100 scans per second.

3/DVAL (DATA VALID) can be used to synchronize array scan to table conversion interval.

Figure 3-7. Altek Corporation Universal OEM Interface

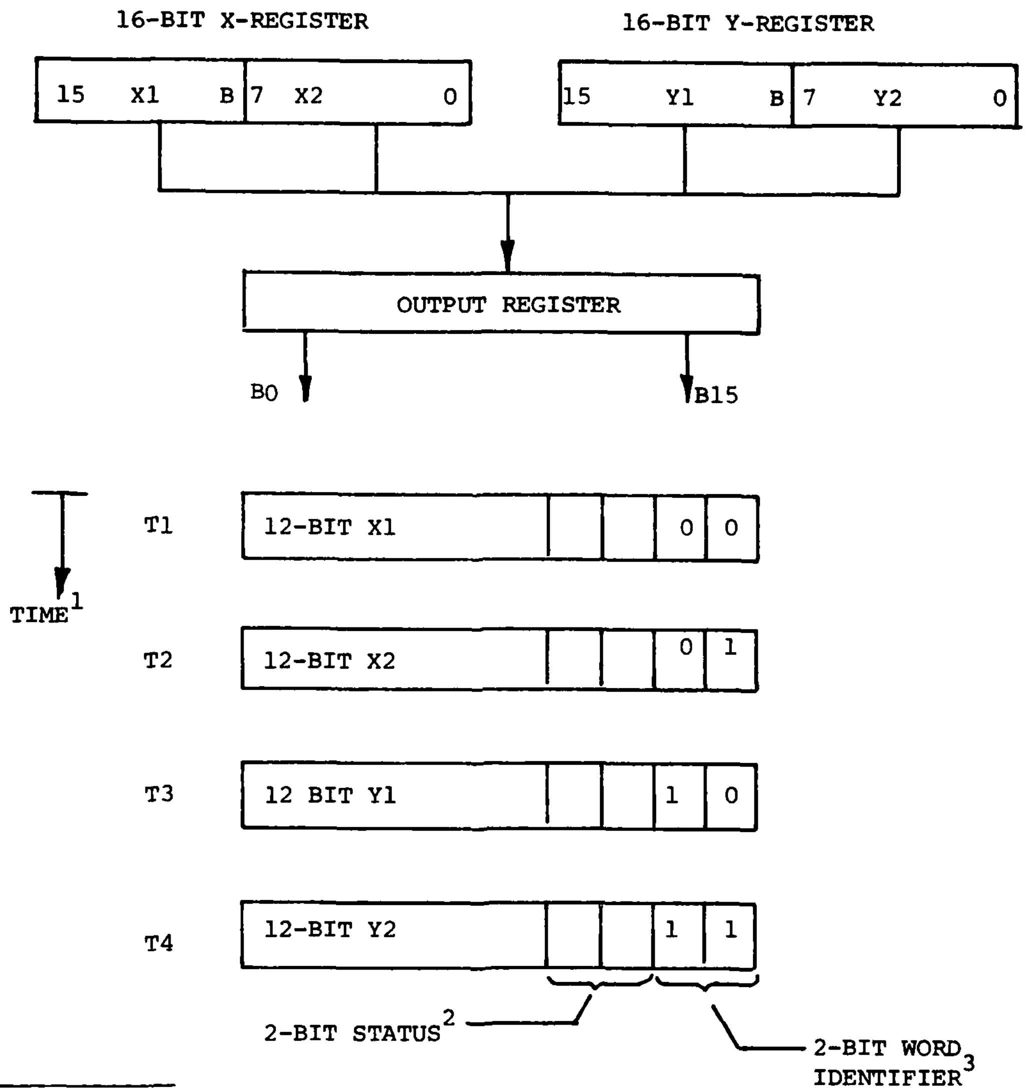


1/INHIBIT can be used to synchronize table output to array scan start. New data is latched into registers only when active.

2/DATA READY can be used to synchronize array scan to table conversion interval.

3/Customer - supplied output drivers required; controller outputs are LS-TTL logic; cable length between controller and IF to be no greater than 1 - foot for optimum performance.

Figure 3-8. GTCO Inc. Datatizer Controller Type 3 Controller

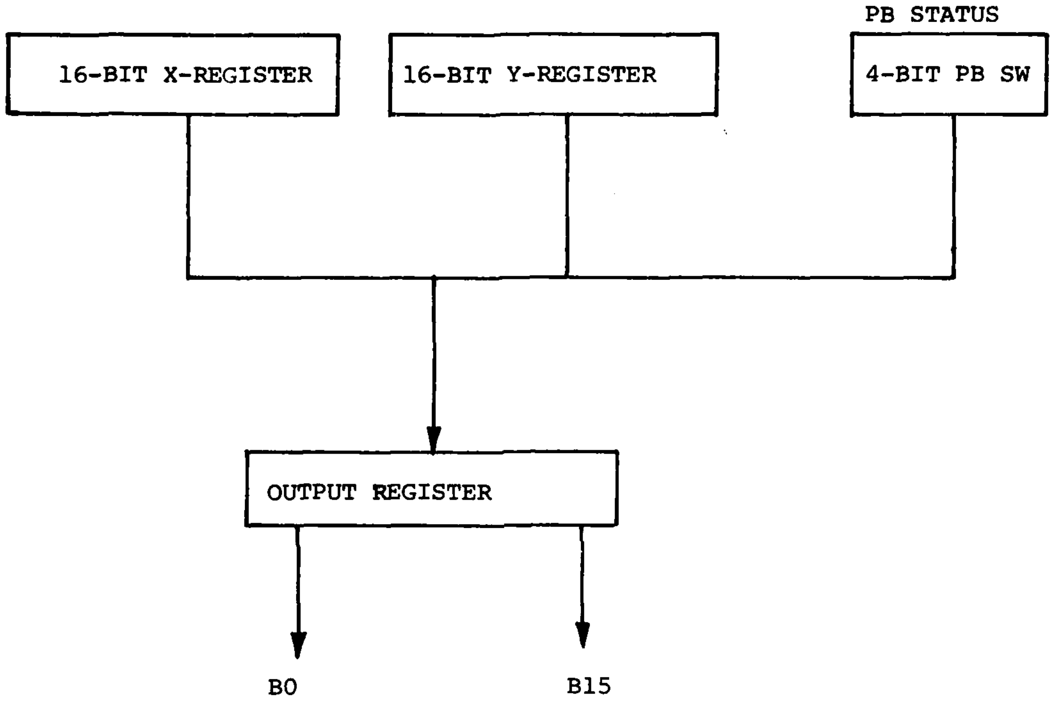


1/ Four word transfer requiring packing format by computer.

2/ 2-Bit status word.

3/ Conversion start scan decoded from 2-Bit word identifier for use as array scan synchronizer.

Figure 3-9. TALOS SYSTEMS Inc. Quad-Sequential Interface



[1]/Efforts to provide fuller descriptions of interface control lines brought no response from Summagraphics

Figure 3-10. SUMMAGRAPHICS Corporation General Purpose Sequential Word Interface[1]

3.7 BACK ILLUMINATION

The Gradicon digitizing table contains a unique method of backlighting manuscripts which makes it well suited to optical sensing of features. As the cursor is moved, a servo system driving a carriage in the x and y coordinate directions follows the cursor. The carriage has mounted on it a DC filament light source to backlight material on the transport table top. Only the area within the cursor viewing port is backlighted. Because the aided-track circle of the scanning cursor reticle is relatively small (approximately 0.1 inch (2.54 mm) in diameter) the illumination can be maintained fairly constant within the area using a diffuser; the spatial illumination characteristic remains constant since the source moves along with the cursor.

The general method for backlighting graphics is to use a number of fluorescent tubes beneath a frosted glass table top. This method has two undesirable characteristics. First, the fluorescent sources are most conveniently powered by the AC line, causing a modulation related to the power frequency. Second, the spacing of the tubes can result in a non-uniform light distribution over the table surface.

The most obvious criteria which can be set for the spatial variation in the backlight illumination would specify that maximum-to-minimum variation should not exceed the signal modulation depth caused by the finest feature detected by the photosensitive array contained in the scanning cursor. In practice, a significant variation can exist if spatial change occurs over dimensions which are relatively large compared to the size of the aided-track circle of the cursor. An automatic balancing amplifier is used in the analog processing circuits for the array output which will maintain a constant average output signal. The extent to which the amplifier will prove effective in dealing with the illumination problem depends on the degree of non-uniformity, i.e. required dynamic range, and spatial frequency of the variations.

No major table manufacturer contacted can provide a unit backlighted by other than a fluorescent field of 10 - 12 tubes spaced across the table. These tubes are powered from the 60Hz line and are not usable for transmissive scanning cursor tracing because of the sensitivity of the array at that frequency. Altek Corporation has, in the past, modified a table to operate the fluorescent tubes at a high frequency (10 to 50 KHz); their experience with DC excitation has shown that a darkening of the tubes occurs at one terminal unless the polarity is periodically reversed.

[Some manufacturers are willing to provide modification to the backlighting source at additional cost, as noted in the descriptive notes detailing digitizer costs.]

3.7.1 High Frequency Excitation

Since the output of an array element is the integrated response to incident light intensity, high frequency excitation of the backlighting source can reduce the variations at the output. If incident intensity is proportional to the excitation power, the resultant output voltage at a given element of the array is

$$e = k(t - \frac{1}{2w} \sin 2\,wt)$$

where

k = electro-optical constant

w = excitation source frequency in radians/sec.

For a 5 ms array integration time, the frequency for which power source fluctuations will cause variation at the output of less than 10% from scan to scan is

$$w \geq 2000 \text{ radians/sec.}$$

or

$$f_s \geq 636 \text{ Hz.}$$

Use of such a source frequency would appear feasible as an alternative to DC excitation.

3.7.2 Photometric Considerations

The expected response of fluorescent backlighting cannot be directly compared to the filament source used in scanning cursor systems for the Gradicon digitizer because of the differing brightness and spectral characteristics of the sources. For example, the spectral distribution of a standard daylight fluorescent tube exhibits several peaks between 400 and 570 µm and is drastically reduced in amplitude beyond 650 µm, the near-IR and IR regions. For a tungsten lamp at 2856K, a broader and smoother response exists over this range--peaking into the IR. Preliminary investigations should readily establish the usability of the fluorescent sources for the scanning cursor system.

SECTION 4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Previously developed Scanning Cursor Systems were used in conjunction with a digitizing table which converted coordinate values at fixed spatial intervals; the majority of commercially available digitizers are based on a time-stream mode of operation (i.e. coordinates are outputted at fixed increments of time yielding a specified number of points converted per second). A major portion of this program was devoted to establishing interface requirements between the Scanning Cursor System and time-stream digitizers compatible with conversion rates and interface options offered by leading suppliers of such equipment. Data transfer concepts and configurations were generated and evaluated in terms of expected performance; implementation costs were provided.

A review of measured performance parameters of two Scanning Cursor Systems developed under previous contracts under the sponsorship of the Rome Air Development Center, Rome, NY indicates that the use of the system can improve digitizing accuracies by factors of greater than 2:1, while simultaneously increasing digitizing rates (throughput) by factors exceeding 2.5:1, over present manual unaided digitizing procedures.

In the course of this program, a number of major suppliers of digitizing equipment were visited or contacted for detailed discussions of interface options, engineering modification costs if required, and standard equipment costs. These suppliers included Altek Corp., Summagraphics Corp., GTCO Corp., Talos Systems, Inc., and Aristographics Corp.

Based on evaluation of the data transfer requirements, a bit-parallel, word parallel, or sequential transfer concept was decided to be the preferred approach. This approach can handle the maximum 100-160 point per second conversion rate specified by the manufacturers, and leaves some leadway for future improvements in these rates.

4.1.1 Expected Performance

Comparison of the spatial-vs-temporal concepts of data conversion indicates that the output copy of graphic material digitized by time-stream methods can be expected to be of higher quality both in terms of resolution accuracy.

Prior system tests with spatially determined conversion points produced a fixed spatial resolution equivalent to the selected spatial grid. This equipment further used a servoed mechanical guide system coupled to optical encoders to produce the digital output coordinate values. This encoding scheme tends to produce excessive points in tracing graphic features with little fine detail and can lead to excessive storage requirements. Time-stream encoding, on the other hand, tends to appropriately regulate the number of data points required to reconstruct the traces, producing high resolution in areas of fine detail and proportionately lower resolution in areas where no fine detail exists. This inherent regulation is a result of the lower tracing speed which necessarily accompanies tracing of highly detailed material.

The electro-mechanical encoding system used introduces uncompensatable errors in the output because of the variable lag of the encoders with tracing speed. At the higher velocities attainable with the aided-track cursor, such errors can be pronounced. This error source is eliminated in magnetic-ranging position measurements.

It is anticipated that digitizing accuracies of $\pm$ .002 inches ($\pm$0.05mm) (the inherent aided-track cursor resolution) can be consistently met by the Scanning Cursor System using time-stream digitizers.

The latest advanced developmental model Scanning Cursor System was capable of digitizing both back-lighted and opaque manuscripts. In the opaque (or reflective mode) tracing operation, illuminating sources are contained within the cursor and performance is thus unaffected by the table surface. In tracing translucent material (transmissive mode operation), cursor performance can be affected by the brightness, spectral characteristics of the background lighting, and distribution of the illumination. The common run of back-lighted tables use 60Hz source fluorescent illumination (as opposed to the DC filament back-light of the tables tested with the Scanning Cursor Systems), which precludes operation in a transmissive mode. Inquiries were made of table vendors for costs to modify the excitation source for operation at higher frequencies to permit transmissive tracing with the photosensitive cursor array taking advantage of its light-integrating property. Some manufacturers will undertake this modification at additional engineering costs; others were unwilling or did not offer to undertake modification to their units.

4.1.2 Table Manufacturers Evaluation

The manufacturer's specifications and price estimates are listed in Tables 4-1 through 4-5 and summarized in Table 4-6. The information contained in these tables was furnished by the manufacturers.

The Data Automation table has been eliminated from the evaluation since their reorganization prevented them from furnishing us with the information required to include their table in the interface analysis. Their re-organization started about a week after we had received the data necessary to perform the table manufacturer identification task. After the first sections of the report were completed; we were informed by Interface Electronics, Inc. that they were building and marketing the Data Automation

Table 4-1

Altek Corp. Specifications and Pricing Data

MANUFACTURER	Altek Corp. Silver Springs, MD 20904 (301) 622-3906	
SPECIFICATIONS	Resolution .001 Conversion rate 100 points/ sec Accuracy ± .005	
PRICE	42 x 60 Data tab digitizer (table surface, 16 button cursor)	6157
	90CController (grid electronic drive)	675
	16-bit x,y parallel register IF card	300
	Power pedestal	990
		8122
OPTIONS	Panel x,y display (hexadecimal)	475
	Back-lighted table (standard)	2850
		3325
		$11,447

BACKLIGHT MODIFICATION COST

Engineering modification	2500
Fabrication	850
	$3350

Fluorescent back-light using 20 KHz excitation.

Table 4-2

GTCO Corp. Specifications and Pricing Data[1]

MANUFACTURER	GTCO Corp. Rockville, MD 20850 (301) 279-9550			
SPECIFICATIONS	Area	42 x 60		
	Resolution	.001		
	Accuracy	± .005		
	Conversion Rate	30-50 points/sec.		
PRICE	DTR-4260 Datatizer DTR-300 Parallel x-y binary controller, power supplies, 5-button cursor)[2]		6040	
	Optional .005 accuracy		700	
	Power Pedestal		1290	
	Optional 50 pt/sec.		1800[3]	
			9830	
OPTIONS	Decimal display			
	DTR-200 Formatter	425		
	DTR-210 Display	200		
		625		
	Translucent top		1200	
	Light box		3450	
			4650	
				$15,105

BACKLIGHT MODIFICATION COST

Engineering Costs	6000
Recurrent Costs	2000
	$8000

Modification will consist of DC excitation of fluorescent tubes.

1/ GTCO digitizers are directed toward the OEM market.

2/ DTR-300 controller has no drive capability; customer-supplied interface board is required with a cable length no greater than 1 foot.

3/ Max. conversion rate is dependent on size of working area; for conversion of a 60 in. lineal length, this rate is decreased to approx. 35-40 pts/sec.

Table 4-3

Talos Systems Inc. Specifications and Pricing Data

MANUFACTURER	Talos Systems Inc. 7419 East Helm Drive Scottsdale, AZ 85260	
SPECIFICATIONS	Area	44 x 60
	Resolution	.001
	Accuracy	± .005
	Conversion Rate	100 pairs/sec.

PRICE	Mod. 8601 (opaque) or 8602 (standard back-lighted)	9975
	Optional .005 accuracy incl. 4 button cursor	630
	Mod. 8043 Quad-Sequential Interface	550
	Mod. 8070 Power base	1160
		12315

BACK-LIGHTED MODIFICATION

Talos has inquired into supplier-availability of components for high frequency source excitation with negative responses. Consequently, Talos is not prepared to undertake lighting modifications. They will, however, supply the table with a standard backlight surface, less lighting, for customer installation of source lighting at a credit of $150 on the purchase.

Table 4-4

Summagraphics Corp. Specifications and Pricing Data

MANUFACTURER	Summagraphics Corp. Fairfield, CT 06430 (203) 384-1344		
SPECIFICATIONS	Area	42 x 60	
	Resolution	.001	
	Accuracy	$\pm$ .005	
	Conversion Rate	100 pairs/sec.	
PRICE	SG-60-OP Summagrid (incl. controller, 5 button cursor, RS-232-C port)	7600	
	General Purpose bit-parallel, Word sequential interface	900	
	Power pedestal	1200	
		9700	
OPTIONS	Back-lighted table (standard)	2500	
			$12,200

BACK-LIGHTED MODIFICATION

In intial discussions on back-light requirements, Summagraphic stated they would investigate alternate sources and cost out modifications. Summagraphics declined to cost out the modifications because of the back-light option. Their concern was overall effect of high frequency or DC backlighting on the scanning cursor and the life span of the fluorescent tubes. They suggested that a 3 phase power source may solve the problems at a much lower cost.

They will provide the engineering necessary to build a table compatible with the scanning cursor.

Table 4-5

Aristographics Corp. Specifications and Pricing Data

MANUFACTURER	Aristographics Corp. Randolph, NJ 07869 (201) 366-7000	
SPECIFICATIONS	Area	39 x 59 inches
	Resolution	.001
	Accuracy	± .004
	Conversion Rate	160 pairs/sec
PRICE	Aristogrid GRT-109 (includes 5-button cursor, RS232 interface, manually adjusted base.)	$14,200

Aristographics appears to have only a limited engineering capability for maintenance purposes. No back-lighting table is available from this vendor; and table modification will be undertaken. This vendor would appear to have very limited equipment capability to adapt the scanning cursor system for operation with their table.

Table 4-6 Table of Digitizer Manufacturer Specifications Summary

Manufacturer[1] Mode	Size	R / A	Sample Rate[4]	Cost[2]	Available IF Option	Comments[3]
Altek Corp. Datatab	42x60	.001 / $\pm$.005	100	11,447	16-bit binary parallel register	Has had experience with "flicker-free" backlight tables in past. Will provide HF backlighting.
GTCO Corp. DTR-4260	42x60	.001 / $\pm$.005	50	15,105	16-bit binary parallel registers	Will provide DC backlighting. Customer-supplied interface driver required.
Summagraphics Corp. Summa-Grid SG-60-OP	42x60	.001 / $\pm$.005	100	12,200	GPIB 8-bit parallel, binary-byte serial	Investigating other sources/means for providing alternate backlighting. Cursor is active element in this system.
Artisto-Graphics Corp. Aristo100 GRT109	40x60	.001 / $\pm$.004	160	14,200	RS232 IF	No engineering capability to modify backlight system. No backlight tables available.
Talos Corp. (Calcomp.) MOD 8601	44x60	.001 / $\pm$.005	100	12,315	Quad-Sequential transfer	Opaque or backlighted table at no cost. No backlight modifications will be undertaken.

R= Resolution
A=Accuracy

NOTE: Data Automation has not been including since they were reorganizing during this study and the required data was not available.

1/ See listing of manufacturers.

2/ See manufacturer sheets for cost break-down for basic digitizer system and I/O option. Costs in this column are given for standard back-lighted table surfaces.

3/ All tables use imbedded grid surfaces and electromagnetic position sensing.

4/ Sample rates shown in manufacturers specifications are maximum rates dependent on interface option, table size, and data transmission option. A full knowledge of table operating conditions is required to determine this specification in a realistic manner.

table. Since they are just getting into the area, the options which will be available (e.g. backlighting) are still undecided.

The ranking of the five table manufacturers is shown in Table 4-7. Since all the manufacturer's had the same resolutions and the specific tables were selected to meet the accuracy requirement of the SOW, rather than the manufacturer's best accuracy, these two characteristics were not included in the rankings. The rankings are based on the following four areas with a maximum weighted total of 4.0.

a. The weighted table price was computed by dividing each table's price into the lowest priced table (i.e. the Altek table had the lowest cost of 11,447 dollars).

$$\text{Weighted table price} = \frac{11{,}447}{\text{manufacturer's price}}$$

b. Engineering availability is one of the key factors, thus this area is assigned a value of one if the manufacturer will supply engineering and a value of zero if engineeering services are not available.

c. The sample rate evaluation is based on the computer optimum rate of 110 points per second. (Reference Section 3.3.) This is computed by dividing the manufacturer's sample rate by the optimum rate of 110. It must be noted that the manufacturer's advertised sample rate was used rather than the actual rate (which could not be established for all vendors). For example:

   1. the advertised rate for GTCO is 50 points per second. This rate is only for the center area of the table and decreases to about 30 when away from the center. The average sample rate is about 34 points per second; and

   2. the Advanced Cartographic Data Digitizing System (ACDDS), being developed for RADC, is equipped with Altek tables. During the experiments to test the table interfaces, the project staff of the ACDDS was able to generate 107 samples per second, which exceeds the advertised rate.

d. The backlighting evaluation is simply a value of zero for "not available" and a value of one for "available". Although backlighting may not be a requirement, the inclusion of this feature only affects one manufacturer who also cannot provide any engineering support.

Table 4-7
Digitizing Table Manufacturer Ranking

Rank	Manufacturer	Basic Table Price	Engineering Availability	Sample Rate	Back-lighting	Weighted Total
1	Altek	1	1	0.91	1	3.91
2	Summagraphics	0.94	1	0.91	1	3.85
3	GTCO	0.76	1	0.45	1	3.21
4	Talos	0.93	0	0.91	1	2.84
5	Aristographics	0.81	0	1.45	0	2.26

In summation, only two companies (i.e. Altek and Summagraphics) can approach the design requirements of the scanning cursor. The third ranking company (GTCO) falls slightly lower in ratings for price and sample rate timings. The fourth and fifth ranked companies (i.e. Talos and Aristographics) fall short mainly in the areas of engineering support and their lack of ability to furnish engineering and logic drawings required for some other company to build the necessary interfaces on a cost-competitive basis.

As previously stated, Data Automation digitizing tables have not been included in these rankings. If Interface Electronics provides the same tables to manufacturers that Data Automation used, these tables will rank somewhere with the top two tables (i.e. Altek and Summagraphics).

4.1.3 Modification Requirements

Outlined below are the hardware and software modifications necessary in order to adapt the current scanning cursor systems to operate with a time-stream digitizer.

4.1.3.1 Hardware modification. The hardware modifications which will be required to adapt the Hewlett Packard (HP) processor to the time-stream digitizer are the following.

a. To eliminate the customized multiplexed interface of the existing system, an additional HP12566B general purpose interface board would be incorporated into the system I/O configuration.

b. Addition of the HP12566B I/O board and the configuration change requires rewiring of the interface cabling and connectors. [These changes effect only the I/O ports to external devices; all other circuitry remains unaffected.]

c. The digitizing table cursor size/shape/structure must be made compatible with the scanning cursor housing which uses the manufacturer-supplied cursor as a base. Figure 4-1 illustrates the structure and dimensions of the current Gradicon cursor. The compatibility between the scanning cursor housing and the cursor base can be accomplished in three different ways. The first would be to obtain an off-the-shelf table with a cursor similar to the Gradicon, then modify the housing to accommodate the cursor. The second approach would be to have the table manufacturer build a cursor to the same specifications as the Gradicon cursor. The table manufacturers, who will provide engineering support, will construct this cursor to the stipulated specifications. The third approach is to purchase only the position sensing element of the manufacturer's cursor and to then configure it within

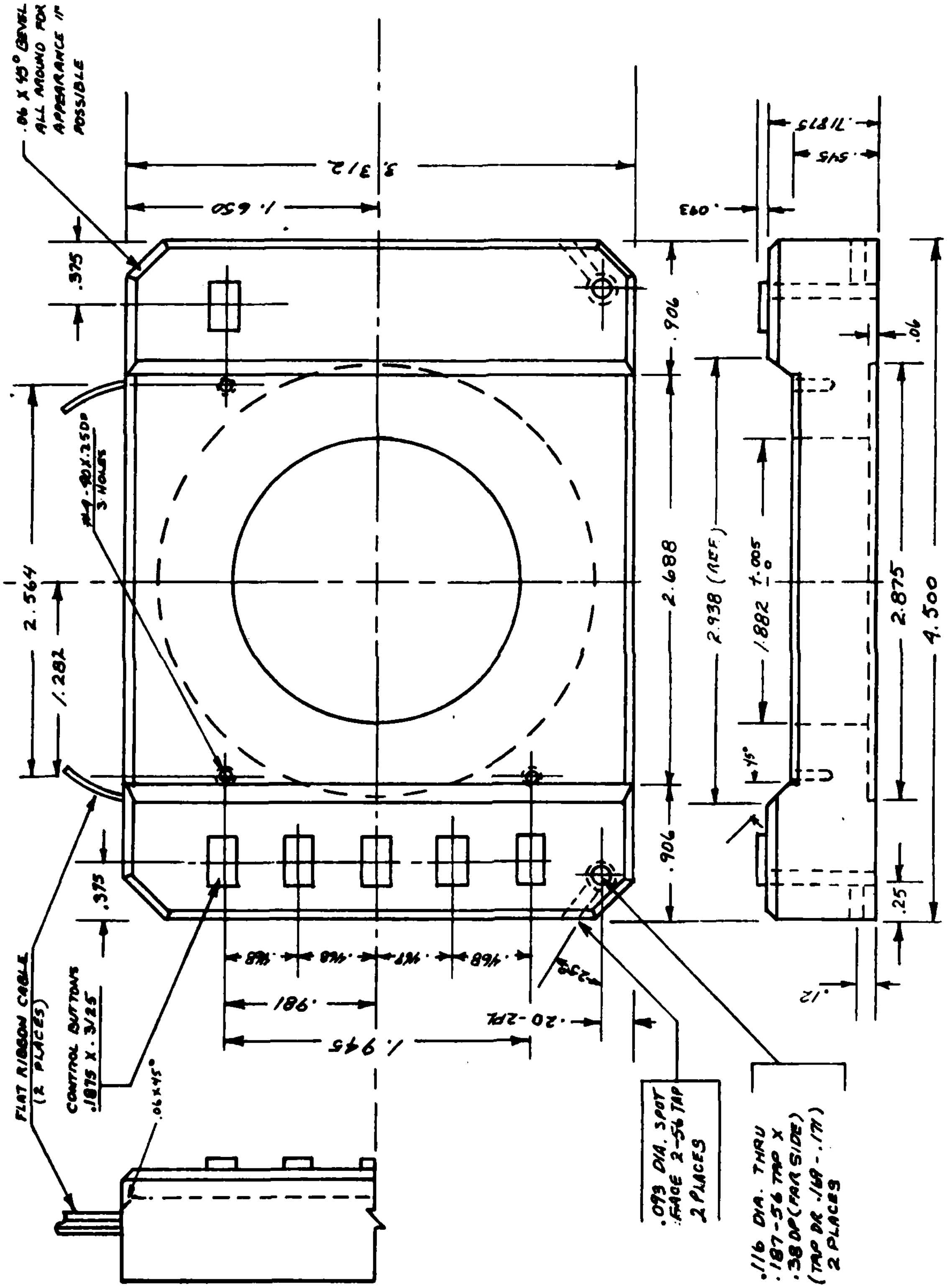


Figure 4-1. Specification Drawing - Gradicon Cursor

the existing scanning cursor design. The present design accommodates 6-switches for data control and status indication. This approach eliminates any major redesign of the scanning cursor assembly and housing; the encoding concepts of the table digitizers reviewed are based on magnetic-sensing by means of a coil embedded about the cursor reticle, accurately centered to eliminate gross errors which would otherwise arise if the cursor is rotated. A similar alignment would be required when the coil mechanism is adapted to fit within the scanning cursor area provided for fitting the coil. The available area which can be designated for mounting the element in the present scanning cursor design lies within a 2-inch (50.8mm) diameter circle centered within the viewing port.

4.1.3.2 Software modification. Software modifications would reflect the changes of the I/O reconfiguration and deletion from the scanning cursor program of those routines peculiar to operation with the Gradicon digitizer. These modifications are required regardless of the transfer method--non-interrupt or interrupt transfer--for inputting table data. These modifications specifically entail:

a. deletion of the multiplexer I/O selection routine;

b. deletion of the vector generation routine; and

c. generation of I/O routines for data transfers via the reconfigured interface.

To implement an interrupt transfer method for inputting data (the existing program makes use of a "wait-for-flag" transfer), an interrupt subroutine would be added to the program to perform a three-word sequential transfer for each data point.

4.2 RECOMMENDATIONS

During the performance period of this effort there have been questions raised about the need to continue developing the scanning cursor, the applicability of the current scanning cursor in a production environment, the availability of a commercial off-the-shelf scanning cursor, and the need for an area array over the current lineal array used in the scanning cursor.

At present, it appears that the availability of a commercial scanning cursor will not be a reality in the near future. Since the scanning cursor concept is the most viable method available to greatly increase data capture rates, it is our opinion that the development of the scanning cursor should be continued in the following areas, concurrently with an independent third party monitoring the efforts to insure an objective test and evaluation.

4.2.1 Back-light Effects

During the analysis portion of this effort, it was computed that a fluorescent back-light powered by a source which exceeds 636Hz excitation would provide a flicker-free light service required by the lineal array in the scanning cursor. After discussions with some of the table manufacturers, it appears that no single best method of providing this flicker-free back-light source has been agreed upon. The following are some of the brief comments of three of these manufacturers.

a. Altek recommends a fluorescent back-light using 20 KHz excitation. Their in-house IR&D has provided them experience in this area and that this is what has worked best in the past. It is also their opinion that DC excitation will darken one end of the fluorescent tubes unless the polarity is reversed at a given time interval.

b. GTCO states that DC excitation is the best way to generate a steady back-light.

c. Summagraphics would not even quote a price to provide a steady back-light table since they were not confident that a high frequency or DC excitation would satisfy this requirement or of the effects of either method on the life-span of the fluorescent tubes.

With these factors in mind, we recommend that a small study be done to evaluate the effects that a high frequency fluorescent back-light will have on the scanning cursor array. In addition, this study should determine if the high frequency excitation has any effect on the life span of the fluorescent tubes and measure the radiation emitted from the power supply to insure it is below the government specification. If the total radiation emitted exceeds government limitations, proper shielding would have to be installed and tested. In order to keep the cost of this study at a minimum, the experiments should be performed on a small table, (e.g. 12 by 12 inches; 305 by 305mm) rather than the 42 by 60 inch (1067 by 1524mm) table.

4.2.2 Scanning Cursor Experiments

Since DMAHTC has a reflective scanning cursor which is not being used, we recommend that this cursor be acquired by RADC and integrated into the Data General (D.G.) S/130 which is in the Geographical Data Processing System (GDPS) at RADC's Experimental Cartographic Facility (ECF).

Figure 4-2 illustrates the two methods that could be used to interface the scanning cursor to the D.G. S/130. The current method would require 1) disconnection of the digitizing table from the D.G. S/130, 2) interfacing the digitizing table to the HP processor, 3) adapting the table cursor for the housing of the scanning cursor, 4) interfacing the HP processor to the D.G. S/130, 5) modification of the HP software and 6) modification of the

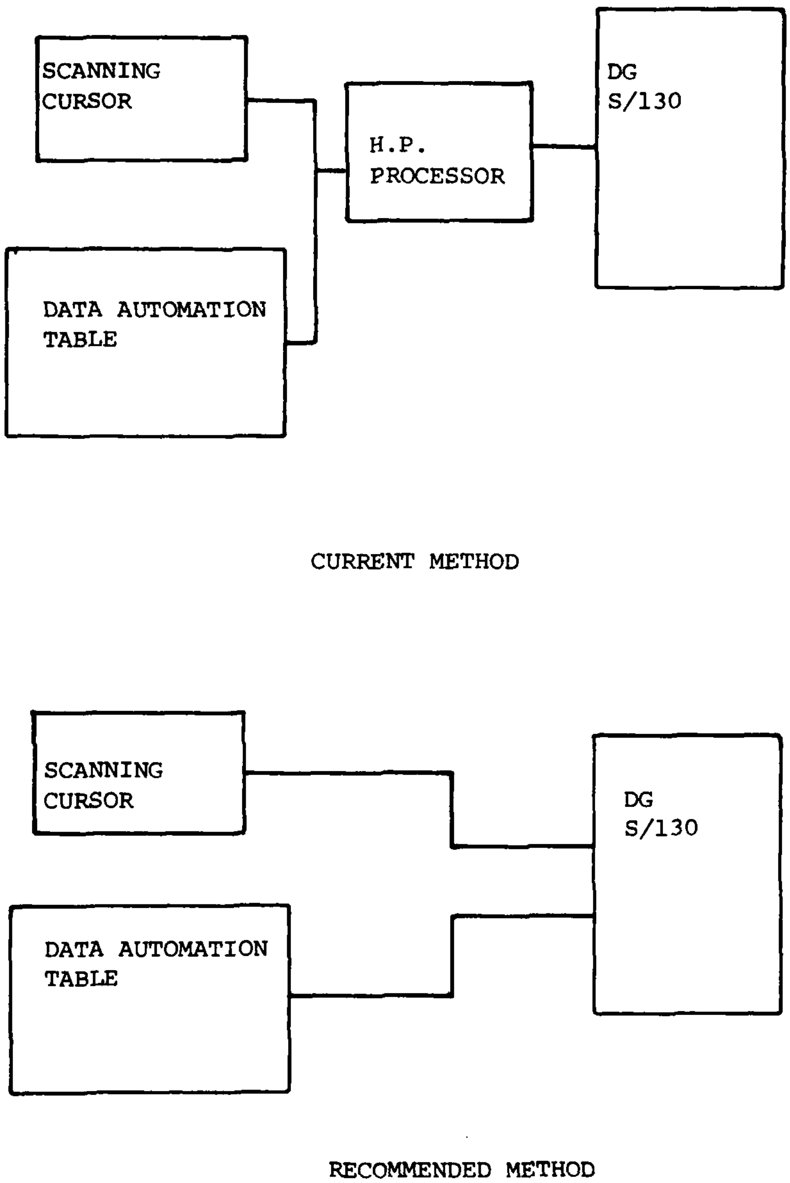


Figure 4-2. Scanning Cursor Interface to GDPS

D.G. S/130 software. Since the HP processor is not equipped with an assembler or compiler, software changes would be very time consuming.

The recommended method would require 1) interfacing the scanning cursor to the D.G. S/130, 2) adapting the table cursor to the housing of the scanning cursor, and 3) developing the scanning cursor software on the D.G. S/130 in a transferable, modular, high level language. With the recommended interface method, the following functions can readily be accomplished.

a. The scanning cursor software could be streamlined and the remaining 'bugs' could be removed. By using a high order language, the software could easily be modified or transferred to another system.

b. The software would be modified to compensate for a physical rotation of the cursor. Thus, a user could rotate the cursor 90 degrees, press a button, and the software would automatically rotate the incoming array data by 90 degrees.

c. Provide noise suppression by developing a low noise analyzer for the signal processor.

d. Incorporate a CRT to monitor the array output during experiments.

e. Perform controlled experiments on the scanning cursor in a pseudo-production environment. By using the S/130, the software can save the table points and the array outputs on disk; any discrepancies between the digitized data and the source can easily be evaluated by reviewing the table X,Y points and the array outputs. This would insure that the analyst would know exactly what caused the discrepancy(ies). This would eliminate the question as to whether the scanning cursor was in error, the software in error, or was the Gradicon unable to keep up with the digitizing rate of 10 inches (254mm) per minute.

One of the major advantages of testing the scanning cursor at RADC is that, when required, arrangements can be made to insure that the system is available for testing and engineering modification.

The existing digitizing table meets the requirements of the reflective scanning cursor. (i.e. It has a parallel interface and a sample rate of 150 points per second.) In a discussion with Interface Electronics, they stated that they would build a cursor which will meet the Gradicon specification.

4.2.3 Area Array Study

The scanning cursor which was evaluated used a lineal array and a servomotor to rotate this array. Although this structure was good for a prototype to evaluate the concept, a production model should contain no mechanical devices. In order to eliminate the mechanical device, an area array should be used in place of the lineal array. A feasibility study should be performed to evaluate the effects of an area array on the scanning cursor concept. As minimum requirements, the following areas should be reviewed and evaluated:

a. the feasibility of providing the increased scan times required for an area array; [the lineal array is scanned only once per each array output, but an area array must be scanned N times, where N equals the number of elements in the array, for each output];

b. effects of fluorescent light on the array (reference 4.2.1);

c. the processor requirements to handle the volume of data from the area array and accurately compute the point prior to receiving the next point; and

d. the requirements of the noise analyzer to balance the array output.

APPENDIX A

INTERFACE SPECIFICATIONS

BACKGROUND

Under a recent contract, RADC has requested a survey of digitizing table manufacturers to adapt RCA's Scanning Cursor System for operation with available tables. The Scanning Cursor System uses a modified table cursor containing a linear photo sensitive array to provide fine correctional terms to the table encoder coordinate values which may be in error due to operator tracing inaccuracies. (Enclosed is a descriptive article on the scanning cursor offering further explanation of the system.)

The existing system developed for RADC has a non-standard interface to an Instronics, Limited "GRADICON" digitizer which outputs values at set spatial increments in either x or y direction. The primary object of the present study program is to investigate use of the scanning cursor equipment with time-based tables (i.e. x and y values are outputted at some fixed time rate). The scanning cursor has the present capability to operate with backlighted or opaque graphic manuscripts. It is desirable to have both tracing modes available; back-light requirements are given in the attachments.

The attached interface description defines the requirements for transfer of encoding table data to the RCA Scanning Cursor System. This system uses a Hewlett-Packard 2108M minicomputer which is transparent to other existing external devices. An HP12566B interface card has been selected for data transfer between the encoding table and the HP computer. This selection and the resultant configurations described were made to:

a. eliminate the need for customized interface circuitry (i.e. use of standardized interfaces); and

b. minimize I/O software changes to the existing scanning cursor program.

Two I/O configurations are described: a 3-channel parallel transfer of 16-bit data words for x,y, and status and a sequential word transfer. If both can be implemented using standard output options offered by the table manufacturer, a note should be made of this fact. The 3-channel parallel transfer has been selected as the primary choice.

BACKLIGHTING REQUIREMENTS

For digitizing back-lighted manuscripts, there is a need for a relatively uniform illumination field. The photo-sensitive array used in the scanning cursor will respond to light fluctuations at power source frequencies. It is necessary to provide a DC back-lighted system. Shading variations (i.e. changes in illumination over the active table area) should not exceed 15-20% to permit reliable operation of the Scanning Cursor System.

DIGITIZING TABLE INTERFACE REQUIREMENTS FOR SCANNING CURSOR SYSTEM

INTERFACE CONFIGURATION

Parallel Word Transfer (Preferred configuration)

Figure A-1 shows the proposed configuration for interfacing the digitizing table to the intermediate Hewlett-Packard (HP) Model 2108 minicomputer used in RCA's scanning cursor system. Three separate output registers (x-word, y-word, s-word) are desired for data transfer to the computer; appropriate flags are necessary to latch the data into the interface registers. ·(The table status will be provided in the s-word, including indications of cursor switches activited.) A compatible timing sequence is shown in Figure A-2.

Optional - Sequential Word Transfer (Figure A-3)

Transfer of the x-word, y-word, and s-word can be achieved via a single device output register by sequential loading of x, y, and s-words with appropriate flags for routing data to the assigned interface. As shown in the figure, a common output bus is used for data transfer; as each word is placed on the output bus, the corresponding flag is to be provided to latch the data into the HP interface register. A compatible timing sequence is shown in Figure A-4.

DEVICE COMMAND LINE

DEVICE COMMAND LEVEL

The Device Command Level from the HP x-word I/O will indicate readiness of the interfaces to accept table data. This signal is reset by computer instruction after the concurrent data set (x, y, and s-words) are transferred.

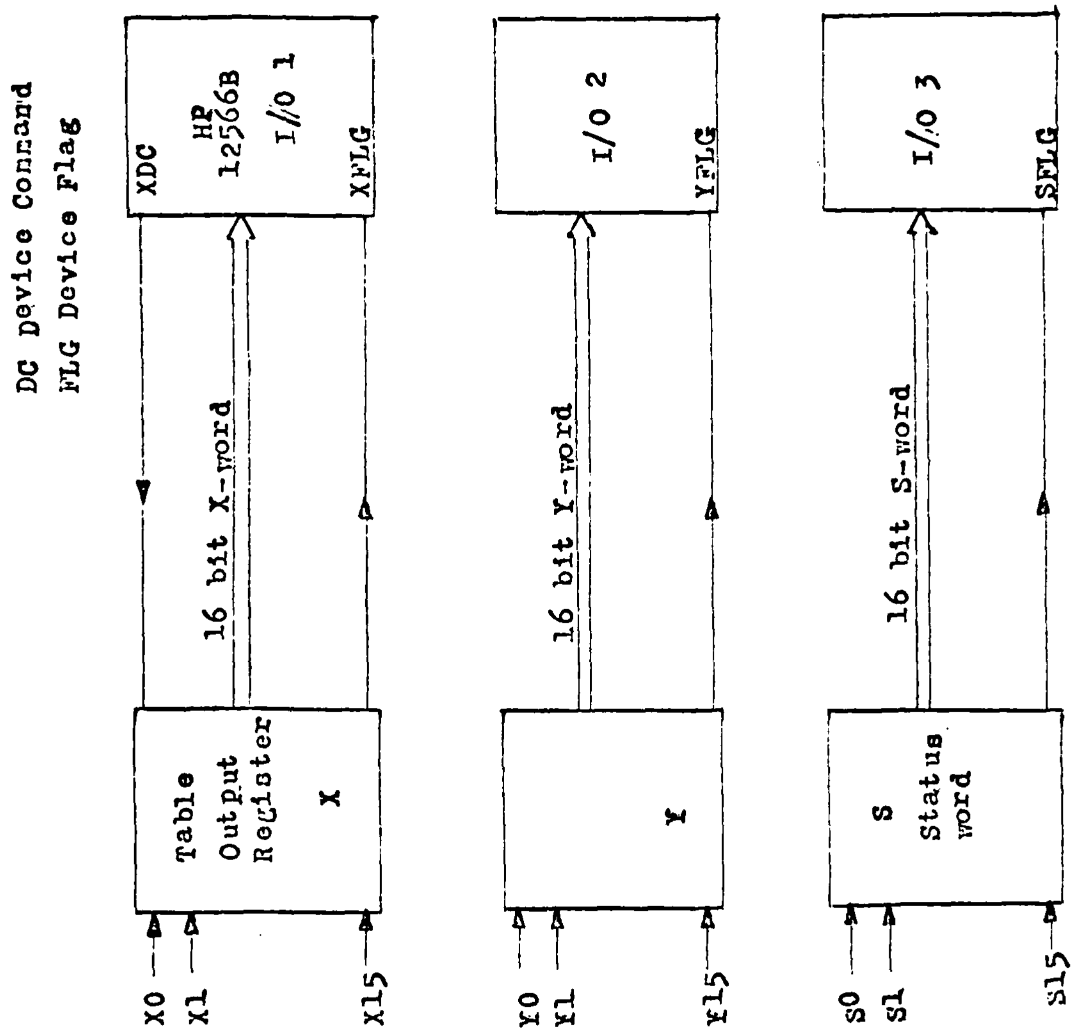
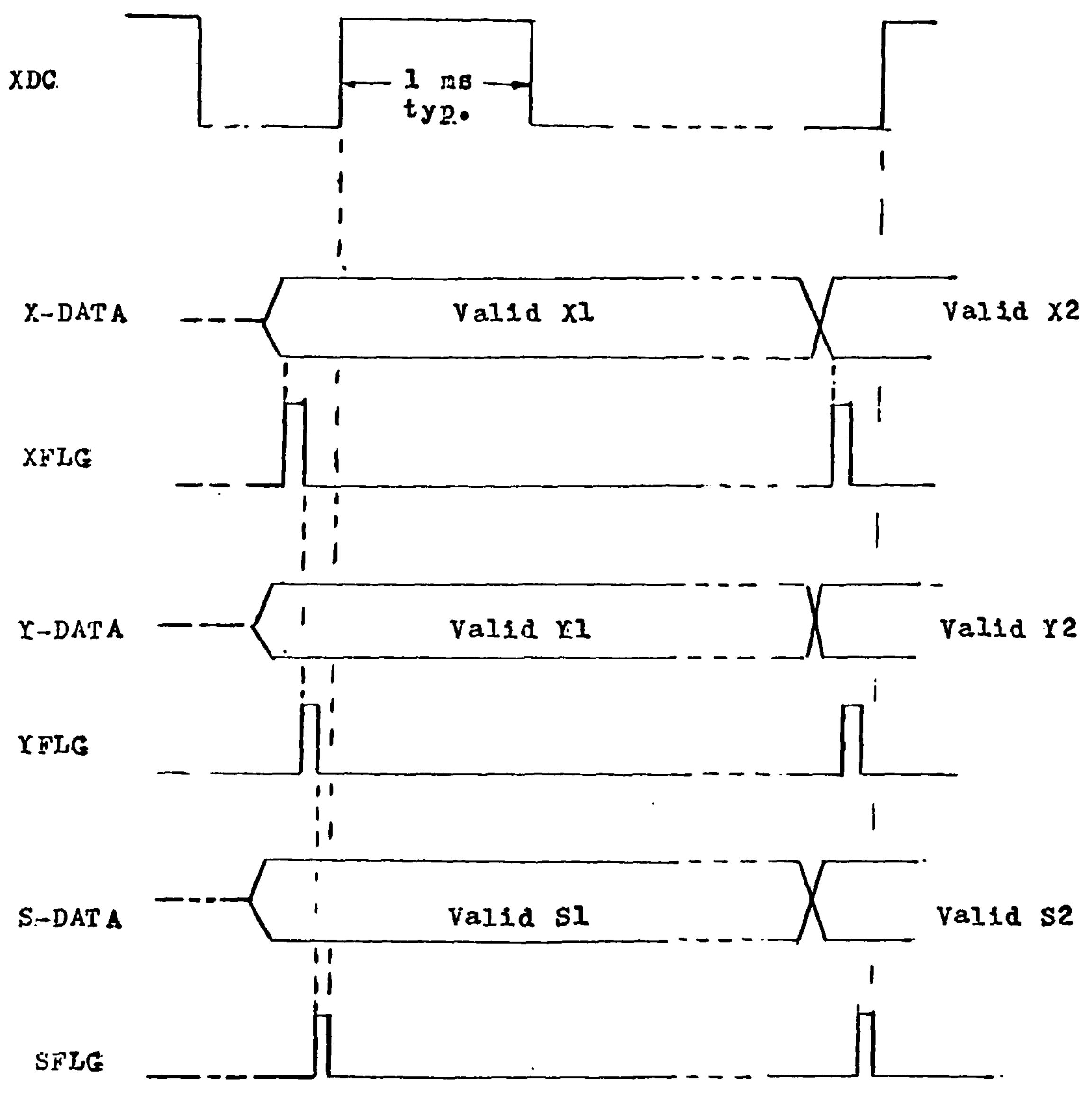


Figure A-1. Parallel Word Transfer Configuration



Notes: 1. FLG pulses strobe data into HP interface.
2. FLG's can occur simultaneously. XFLG can be used to strobe X, Y, and S data.

Figure A-2. Timing Diagram for Parallel Word Transfer

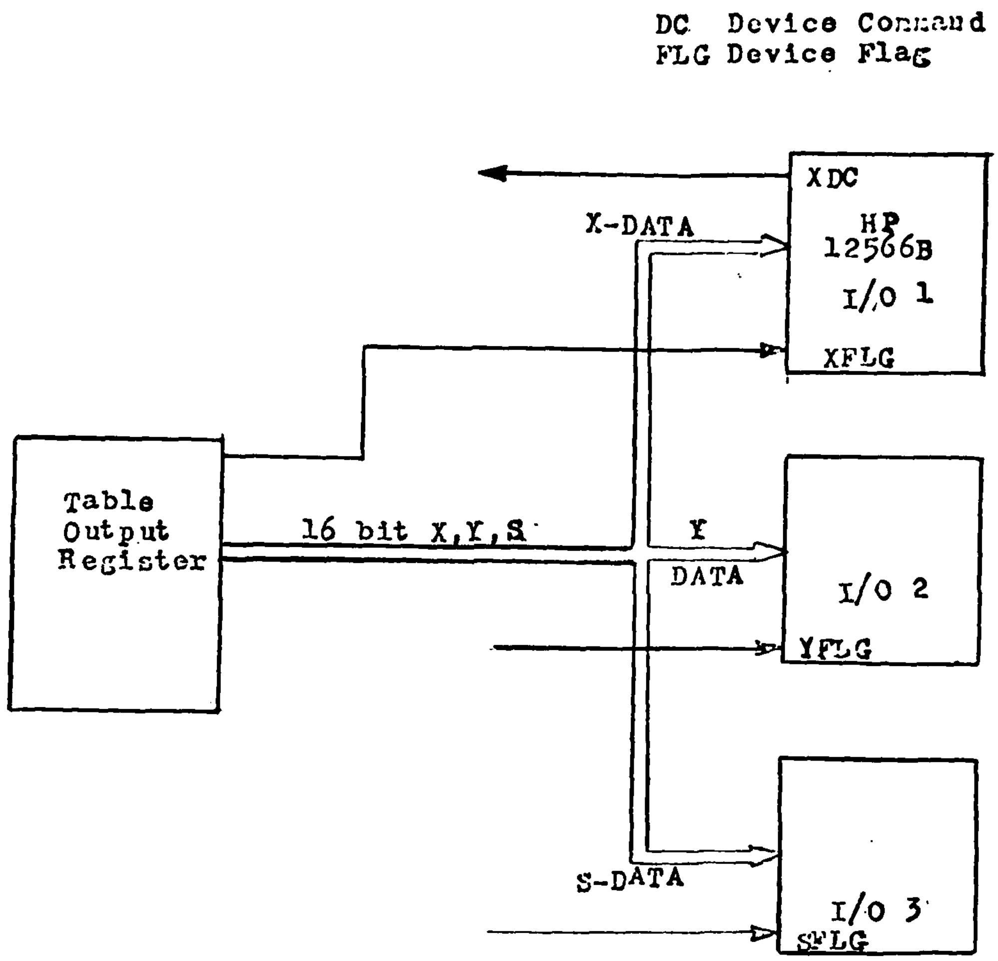


Figure A-3. Sequential Word Transfer Configuration (Optional)

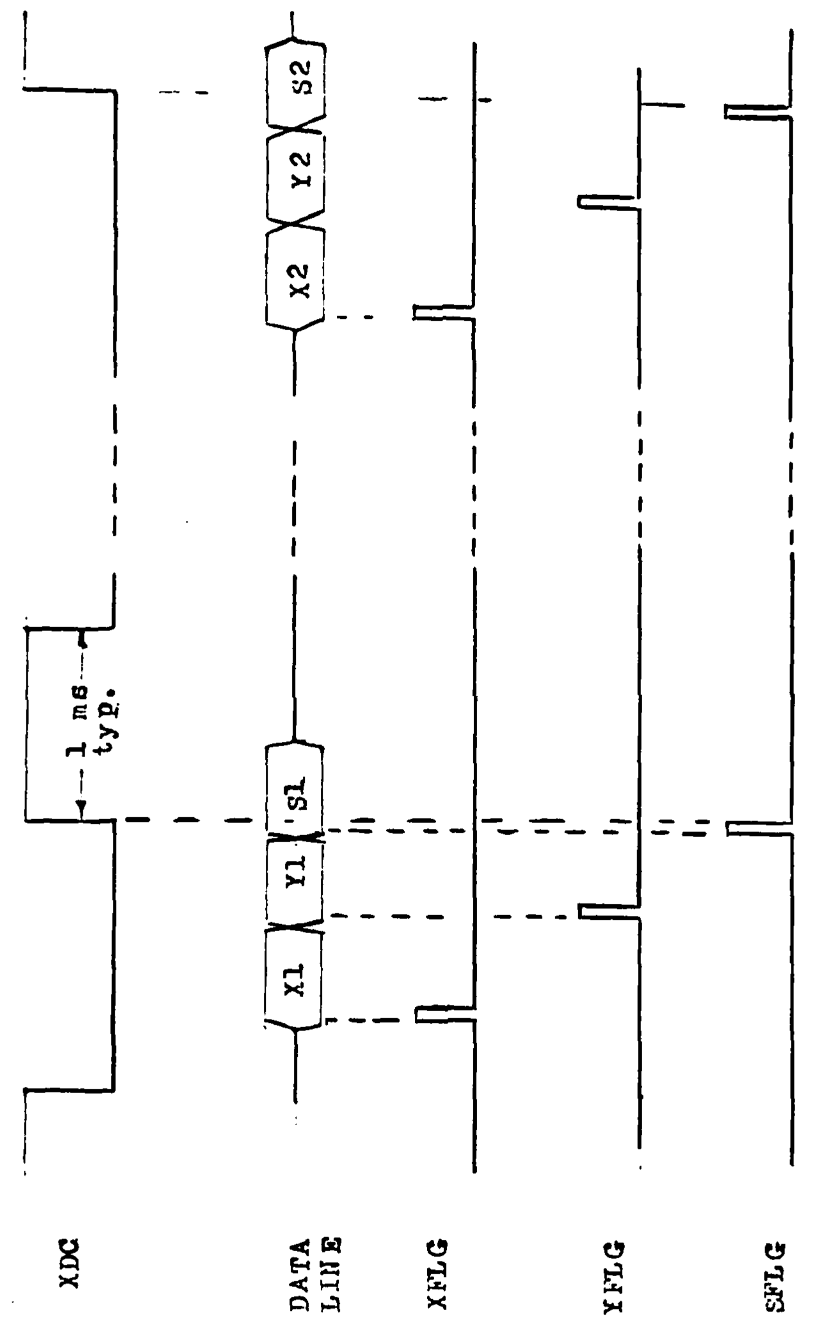


Figure A-4. Timing Diagram for Optional Sequential Word Transfer

DATA FORMAT (X AND Y WORDS)

FORMAT SPECIFICATIONS

The format will be 16-bit parallel, binary. Negative logic will be used for data bits (ground true).

INTERFACE DRIVE

REQUIREMENTS

Interface drive requirements are defined in Figures A-5, A-6, and A-7 showing the appropriate circuits and signal definitions. All interface lines are to be TTL-compatible. The length of the interconnection cables will not exceed 15-feet. Each cable (x, y, and s cables) provides 36 twisted-pair signal lines.

HP12566B INTERFACE CARD

OPERATING DESCRIPTION

The microcircuit interface card is a multi-use interface card designed to transfer data between an HP computer and a peripheral I/O device. Two registers are provided on the card. The output storage register provides temporary storage of data sent out by the computer; the input storage register provides temporary storage of data sent to the computer from the I/O device. Control signals from the computer cause the interface card to generate a Device Command signal which turns on the I/O device. When device operation is complete, the device sends a Drive Flag signal to the interface card. The computer accepts input data when the Device Flag signal is received or, if the computer interrupt system is in use, when the interface card sends an interrupt signal to the computer.

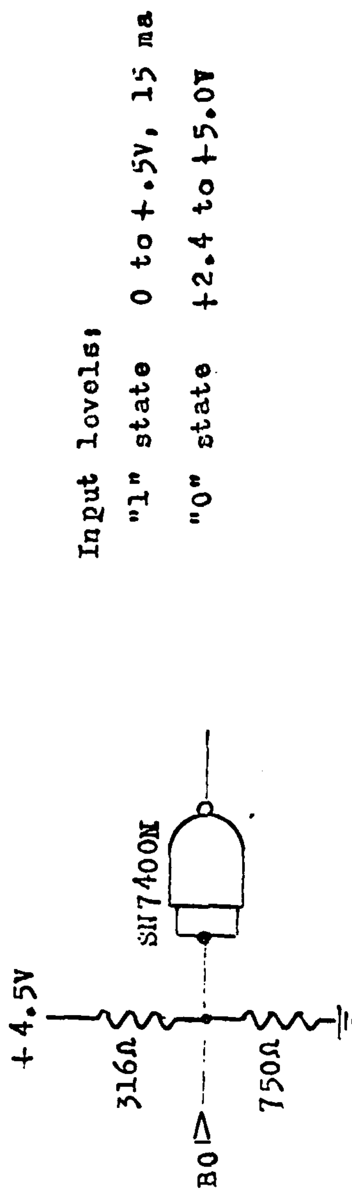


Figure A-5. Typical Data Input Circuit

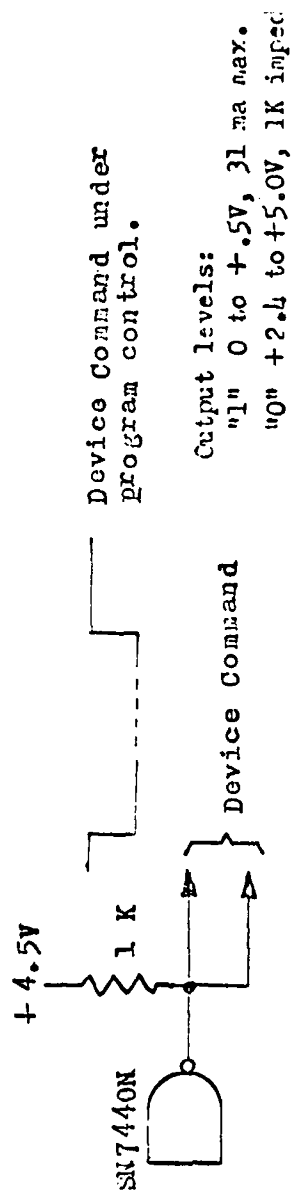


Figure A-6. Device Command Driver

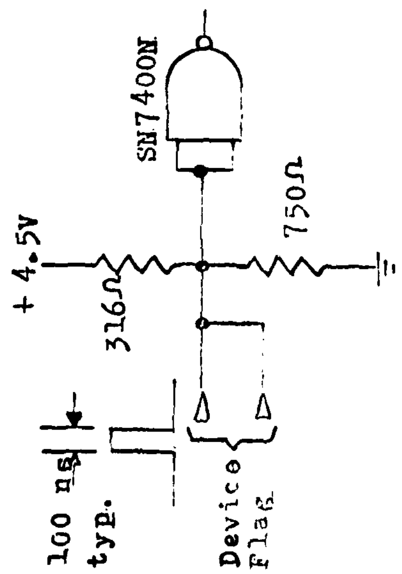


Figure A-7. Device Flag Input Circuit

APPENDIX B

REFERENCES

RELATED CONTRACTS

The following are related contracts, awarded by RADC, that cover feasibility studies of transmissive and reflective scanning cursor systems as well as the design of hardware to perform the analog and digital signal processing required to generate correction terms from the self-scanned photosensitive array on which the aided-track concept is based.

a.	Scanning Cursor Techniques	F30602-74-C-0318
b.	Scanning Cursor Device	F30602-76-C-0443
c.	Scanning Cursor Techniques II	F30602-77-C-0243
d.	Reflective Scanning Cursor	F30602-78-C-0322

PUBLICATIONS

The publications listed below detail the evaluation of the transmissive scanning cursor within an operational environment.

a. G. Hunka and S. Damon, "Engineering Evaluation of an Aided-Track Digitizing Cursor System", Proc. of the American Congress on Surveying and Mapping, 39th Annual Meeting, March 1979.

b. G. Hunka, "Aided-Track Cursor for Improved Digitizing Accuracy", Photogrammetric Engineering and Remote Sensing, vol. 44, no. 8, pp. 1061-1066, August 1978.

c. "Scanning Cursor Device", RADC Technical Report 78-211, RCA, October 1978. (A062552)

d. "Scanning Cursor Techniques", RADC Technical Report 76-363, RCA, December 1976. (A034599)

e. "Scanning Cursor Techniques II", RADC Technical Report 79-2, RCA, February 1979. (A067318)

PATENTS

A patent issued as a direct consequence of the work performed under the contracts is the following:

"Optical Cursor Tracking Correction System", US Patent No. 4, 114,034, 12 September 1978, assigned to RCA Corporation.

TRAINING MANUALS

Training manuals for the installation, use, and maintenance of the Reflective Scanning Cursor system (Volume I: User's Manual, Volume II: Installation and Maintenance Manual, and Volume III: Computer Program Manual) are contractual items under the present contract covering this document. These manuals include schematics and parts lists for the equipment. Program documentation (Volume III) contains the RSC program listing as assembled for the Hewlett-Packard 2108M computer system used in correcting the table data prior to transfer into a data base file.

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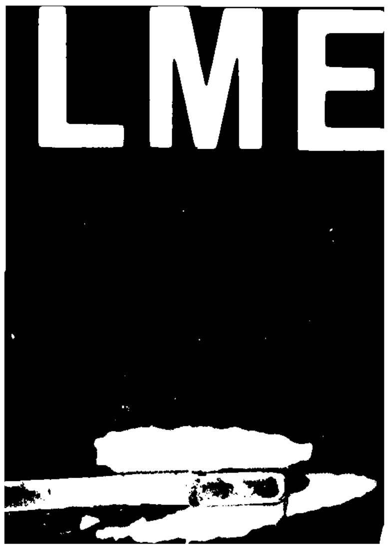
LME